SRI/USEPA-GHG-VR-19
September 2002

Environmental Technology Verification Report

COMM Engineering, USA
Environmental Vapor Recovery Unit (EVRU^{TM})

Prepared by:

Greenhouse Gas Technology Center
Southern Research Institute

Under a Cooperative Agreement With
U.S. Environmental Protection Agency

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Greenhouse Gas Technology Center

A U.S. EPA Sponsored Environmental Technology Verification (ETV) Organization

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Prepared by:
Greenhouse Gas Technology Center
Southern Research Institute
PO Box 13825
Research Triangle Park, NC 27709 USA
Telephone: 919/806-3456

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U.S. Environmental Protection Agency
Office of Research and Development
National Risk Management Research Laboratory
Air Pollution Prevention and Control Division
Research Triangle Park, NC 27711 USA

EPA Project Officer: David A. Kirchgessner

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1.0 INTRODUCTION

1.1 BACKGROUND

The U.S. Environmental Protection Agency's Office of Research and Development (EPA-ORD) operates the Environmental Technology Verification (ETV) program to facilitate the deployment of innovative technologies through performance verification and information dissemination. The goal of ETV is to further environmental protection by substantially accelerating the acceptance and use of improved and innovative environmental technologies. Congress funds ETV in response to the belief that there are many viable environmental technologies that are not being used for the lack of credible third-party performance data. With performance data developed under this program, technology buyers, financiers, and permitters in the United States and abroad will be better equipped to make informed decisions regarding environmental technology purchase and use.

The Greenhouse Gas Technology Center (GHG Center) is one of six verification organizations operating under the ETV program. The GHG Center is managed by EPA's partner verification organization, Southern Research Institute (SRI), which conducts verification testing of promising GHG mitigation and monitoring technologies. The GHG Center's verification process consists of developing verification protocols, conducting field tests, collecting and interpreting field and other data, obtaining independent peer-review input, and reporting findings. Performance evaluations are conducted according to externally reviewed verification Test and Quality Assurance Plans (Test Plan) and established protocols for quality assurance.

The GHG Center is guided by volunteer groups of stakeholders. These stakeholders offer advice on specific technologies most appropriate for testing, help disseminate results, and review Test Plans and Verification Reports (Report) and Verification Statements. The GHG Center's Executive Stakeholder Group consists of national and international experts in the areas of climate science and environmental policy, technology, and regulation. It also includes industry trade organizations, environmental technology finance groups, governmental organizations, and other interested groups. Industry-specific stakeholders provide guidance on GHG Center's verification testing strategies related to their area of expertise. They also peer-review key documents prepared by the GHG Center.

The GHG Center's Oil and Natural Gas Stakeholder Group has voiced support for the ETV program mission, and has identified a need for independent third-party verification of cost effective methane (CH_4) and carbon dioxide (CO_2) emission reduction. The GHG Center has conducted several verifications applicable to the oil and natural gas production, processing, and transmission sectors. This Report documents the testing plans for a new technology that recovers and utilizes vapors from crude oil storage tanks employed in the production and processing sectors.

Approximately 252,000 natural gas production wells and 575,000 crude oil wells exist in the United States. Most of these operations produce large volumes of relatively low-pressure vent gas from different process equipment. According to two separate EPA methane emissions inventory estimates, about 30 billion cubic feet (Bcf) of CH_4 is annually vented from crude oil storage tanks (EPA 1999, ICF 1997). This is the most significant source of vented emissions from the production sector, representing between 35 and 44 percent of total emissions. A large fraction of the gas is CH_4 (30 to 60 percent), and the remaining gas species include non-methane organic compounds and hazardous air pollutants (HAPs). Depending on the site's size and emission potential, the low-pressure gas can be either disposed of (e.g., vented or flared), or recovered and used.

Disposal options are relatively easy to implement and can reduce hazardous and toxic air pollutants. However, disposal options do not make use of the high energy content associated with the gas, they produce large volumes of GHG and other emissions, and when flared, the aesthetic quality of communities is lowered. Many sites use vapor recovery units (VRUs) to capture hydrocarbon vapors that normally vent from production area oil storage tanks. A booster compressor pressurizes the recovered gas and supplies it to a natural gas sales pipeline. VRUs are most often used when the recovered gas can be sold for the value of CH_4 (natural gas) and other hydrocarbons in the vapor.

COMM Engineering, USA (COMM), located in Lafayette, Louisiana, has requested that the GHG Center perform an independent verification of their Environmental Vapor Recovery Unit (EVRU™) at a gas and condensate production facility operated by TotalFinaElf E&P, USA, Inc. (TFE) near McAllen, Texas. The EVRU collects low-pressure vent gas from the site's condensate storage tanks. The recovered gas is pressurized and injected into a natural gas pipeline for sale. The EVRU verification test quantified vent recovery rate, emission reductions, total installed cost, and annual gas savings.

The test was conducted in partnership with EPA's Natural Gas STAR Program, which is managed by the EPA Office of Air and Radiation (EPA-OAR) under a partnership between EPA and the oil and natural gas industry. The program maintains a membership of over 90 partner companies, which are committed to implementing cost-effective CH4 reduction technologies. The EVRU verification test was executed to provide objective performance data to this industry group, as well as to the GHG Center's Oil and Gas Stakeholder Group.

The Test Plan, titled *Test and Quality Assurance Plan for the COMM Engineering, USA Environmental Vapor Recovery Unit (EVRU™)* (SRI 2002), provides the verification test design, measurement, and quality assurance/quality control (QA/QC) procedures. It can be downloaded from the GHG Center's Web site (www.sri-rtp.com). The Test Plan describes the experimental design, rationale, testing and instrument calibration procedures planned, and specific QA/QC goals and procedures. The Test Plan was reviewed and revised based on comments received from COMM, TFE, and the EPA Quality Assurance team. The Test Plan meets the requirements of the GHG Center's Quality Management Plan (QMP), and satisfies the ETV QMP requirements. In some cases, deviations from the Test Plan were required. This Report discusses these deviations, and the alternative procedures selected for use.

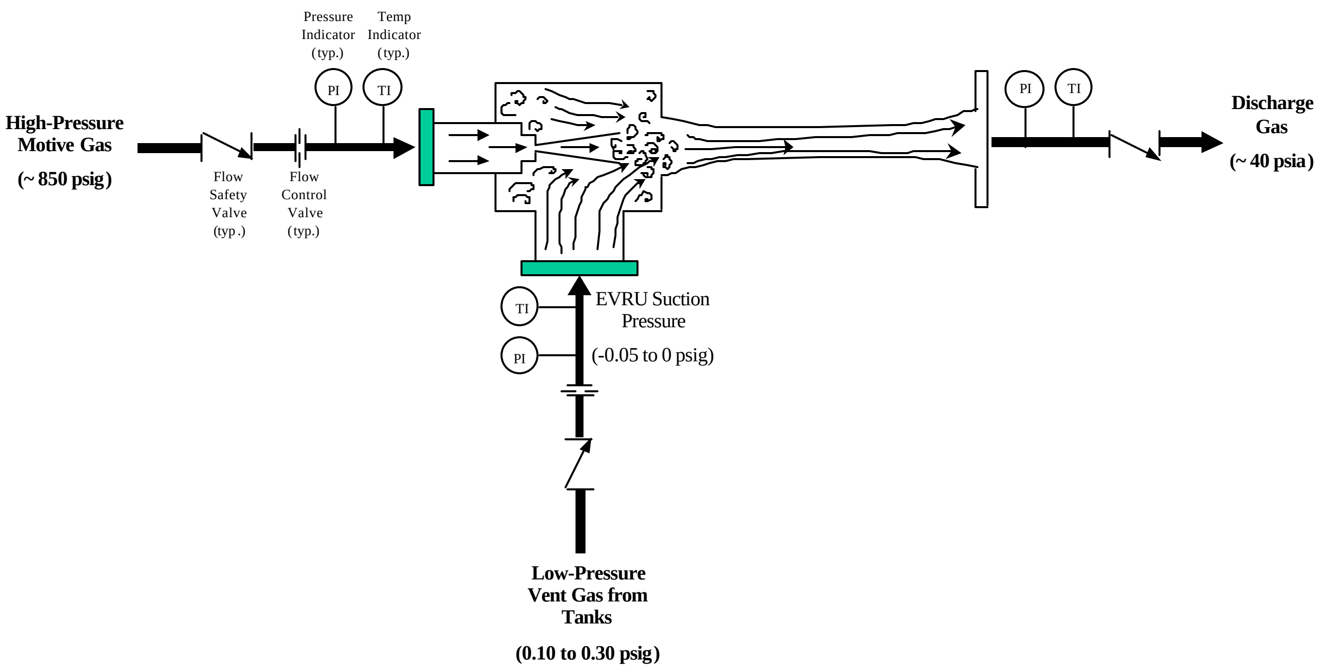
The remaining discussion in this section describes the EVRU technology, summarizes performance parameters that were verified and their testing strategy, and includes a description of the TFE test facility. Section 2.0 presents the test results, and Section 3.0 assesses the data quality of each verification parameter. Section 4.0, submitted by COMM, presents additional information regarding the EVRU technology. Information provided in Section 4.0 has not been independently verified by the GHG Center.

1.2 EVRU TECHNOLOGY DESCRIPTION

The EVRU is a non-mechanical eductor or a jet pump that captures low-pressure hydrocarbon vapors. It requires high-pressure motive gas to entrain the low-pressure vapors emanating from condensate storage tanks. The combined discharge gas stream exits at an intermediate pressure, which can be used on site as fuel or re-pressurized with a booster compressor and injected into a natural gas transmission line for sale. It is a closed loop system designed to reduce or eliminate emissions of greenhouse gases (CH_4 and CO_2), volatile organic compounds (VOCs), HAPs, and other pollutants present in vent gas.

Figure 1-1 is a schematic of the EVRU. The core element is an eductor system which operates on the venturi principle. The EVRU contains flow safety valves, flow control mechanisms, pressure sensing, and temperature sensing devices which allow the system to operate under varying vent gas flow rates. Pressure and temperature isolating valves (not shown) are also installed in the motive gas line to allow replacing or repairing EVRU components.

FIGURE 1-1. THE COMM EVRU



The facility's existing dehydrated high-pressure natural gas pipeline supplies motive gas. A pressure sensor monitors the motive gas pressure; its output signal controls the valve and regulator which maintain the gas flow at the design pressure (typically range of 600 to 850 pounds per square inch, gauge [psig]). The motive gas flows through a venturi orifice situated in a mixing chamber, and creates a differential pressure within the EVRU jet pump. The mixing chamber contains a port which allows low-pressure vent gas (0.1 to 0.3 psig) to be drawn into the chamber due to the partial vacuum created by the motive gas as it expands through the eductor nozzle. The low-pressure vent gas drawn into the eductor mixing chamber combines with the motive gas, and exits the eductor discharge line at an intermediate pressure (i.e., less than the inlet motive gas but greater than the low-pressure gas being drawn into the mixing chamber). The ratio of motive gas to vent gas typically ranges from 3.7 to 5.7 scfm/scfm or 2.0 to 3.0 lb/lb.

At the test facility, a pipeline conveys the discharge gas to a booster compressor which compresses the gas to meet high-pressure natural gas pipeline specifications. Discharge gas pressure and temperature sensors assist operators with the control of the mixed fluid departing the eductor. All process streams contain flow safety devices to prevent backflow (e.g., into the tanks) and over-pressurizing of all components upstream of the flow safety devices. Pressure and temperature isolating valves (not shown) are provided in all process streams to replace or repair the flow sensors.

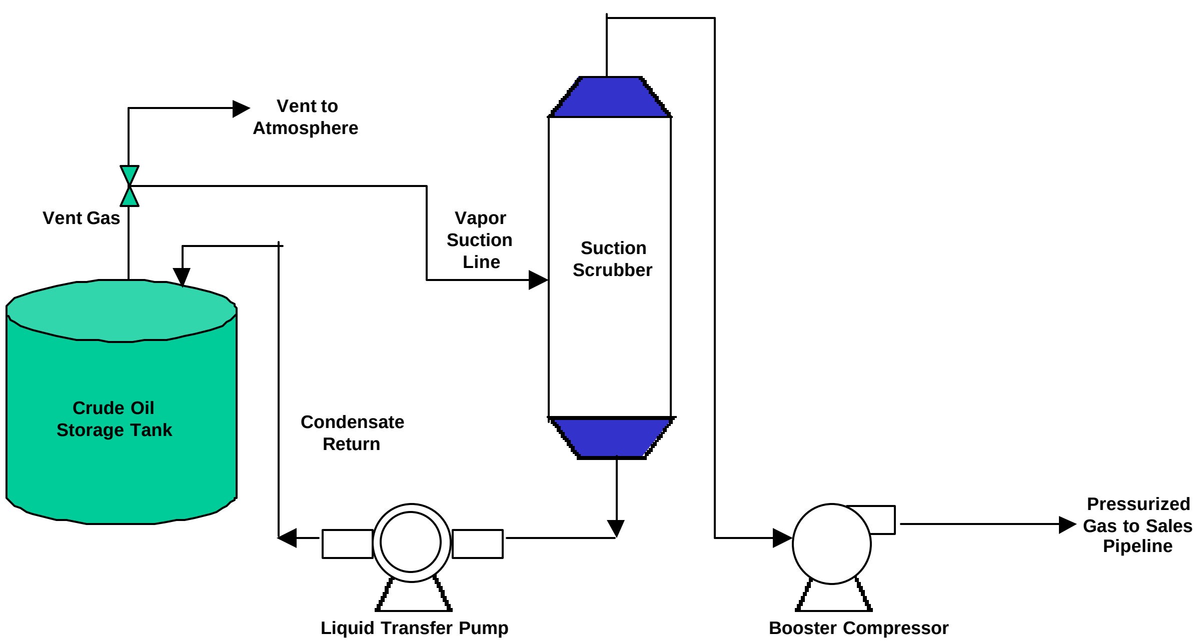
Depending on the volume of low-pressure gas to be recovered, multiple eductor jet pumps may be installed in the EVRU system. When connected in series, the discharge line is connected to the inlet line of a succeeding jet pump prior to discharge to a booster compressor. When connected in parallel, several different sized jet pumps or combinations are brought on line depending on the available flow of low-pressure gas. This parallel system was employed at the TFE site.

1.3 TEST FACILITY DESCRIPTION

The TFE – El Ebanito site is an exploration and production (E&P) facility that handles separation of natural gas and crude oil condensate product, gas compression, and gas dehydration from wells located within a 5-mile radius. It is located approximately 30 miles northwest of McAllen, Texas. In a typical year, daily crude oil production ranges between 900 and 1,200 barrels per day.

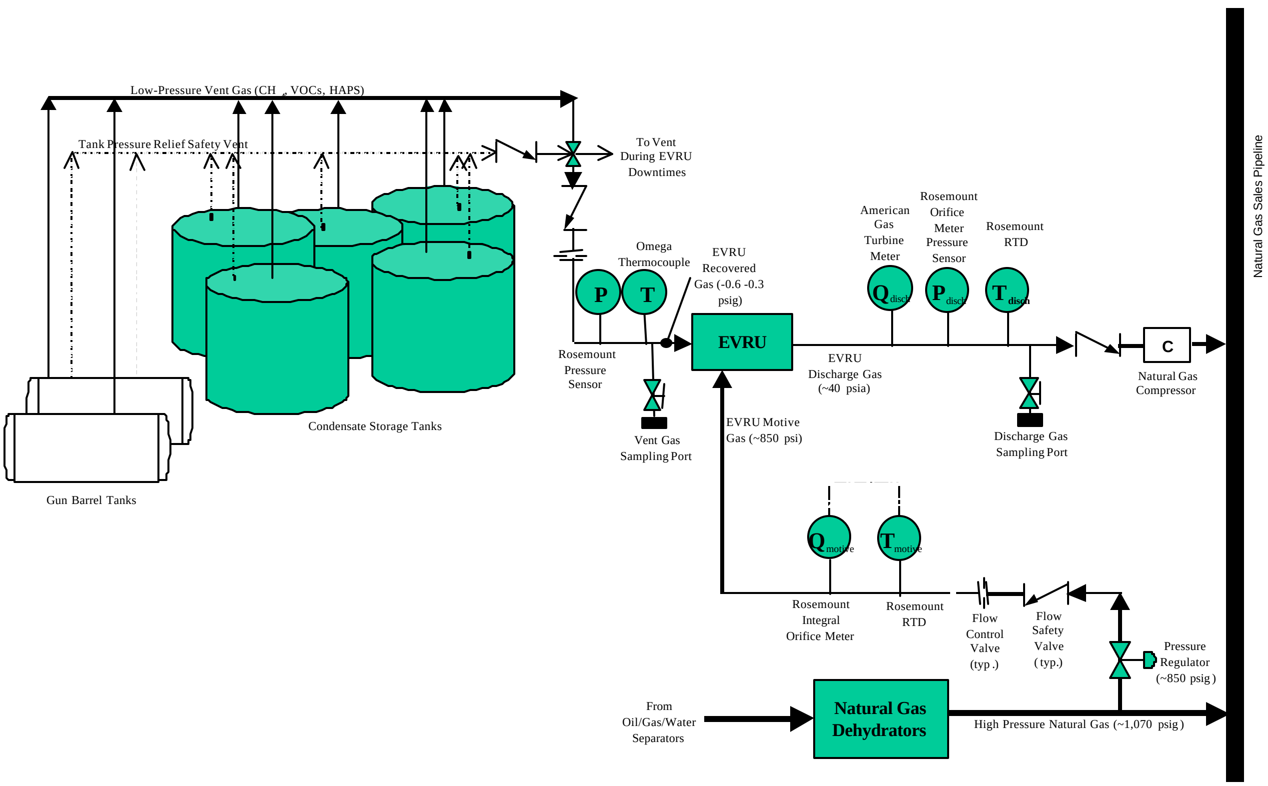
Prior to using the EVRU, the TFE test site employed a conventional VRU system (Figure 1-2) to recover vent gas from five fixed roof crude oil stock tanks (400 barrels capacity) and two gun barrel tanks (750 barrels capacity). In the conventional VRU system, hydrocarbon vapors are drawn out of the tanks under low-pressure, and are first piped to a separator (suction scrubber) to collect any liquids that condense. The liquids are then recycled back to the storage tanks, and the vapors are pulled into a booster compressor which provides a low-pressure suction for the VRU system. The vapors are then metered and routed to a pipeline for sale. Gas recovery efficiencies of 90 to 98 percent have been reported for a typical VRU system (EPA 1995). However, recurring mechanical failures in the existing VRU at the test site have resulted in periodic downtimes, lost product, increased operation and maintenance requirements, and higher emissions due to venting during downtime. TFE operators have reported that their conventional VRU system was down 10 to 15 percent of the time and may have recovered less than 90 percent of the gas while operating. During downtimes, the vapors from the storage tanks were vented directly to the atmosphere. For these reasons, the site has elected to evaluate the EVRU and serve as the host facility for this verification.

Figure 1-2. Simplified Diagram of a Conventional VRU System



Existing vent lines bring the vapors from all seven tanks into a common header (6-inch diameter) which was connected to a 2-inch suction line of the EVRU. The manifold and EVRU skid were located near these tanks. A 2-inch diameter pipeline was used to supply motive gas to the EVRU. The motive gas line includes a pressure regulator and a flow controller to maintain a design pressure of 850 psig. A 4-inch diameter pipeline, operating at approximately 40 pounds per square inch, absolute (psia), conveyed the discharge gas to the facility's booster gas compressor, located approximately 25 feet away. The booster compressor pressurized the gas and injected it into the sales gas pipeline. A schematic of the EVRU installation and the GHG Center measurement instruments is shown in Figure 1-3, and a picture of the installed system at TFE is shown in Figure 1-4.

Figure 1-3. The COMM EVRU Installation and GHG Center Measurement Instruments at the Test Site



The EVRU's primary purpose is to collect and transfer low-pressure vent gas for use. The quality and quantity of gas evolving from each stock tank varies according to many factors, including condensate production rate and composition, how long it stays in the tank (i.e., how frequently the inventory turns over), separator operating conditions, ambient temperature, and atmospheric pressure.

The secondary purpose of the EVRU is to control stock tank pressure changes caused by flash gas being released from the stored condensate, and working and standing losses due to condensate transferring activities. The tanks must be maintained at a slightly positive pressure to avoid air contamination or over-pressurization during all phases of a typical tank duty cycle. Each tank is equipped with a pressure relief vent (PRV) which automatically activates when the tank pressure exceeds approximately 4 oz (or 0.25 psig) above atmospheric levels. The gas is directly vented to the atmosphere until the pressure decreases to the specified levels.

Figure 1-4. The Installed COMM EVRU System

The EVRU is designed to maintain internal tank pressures to range between 0.10 and 0.30 psi over local atmospheric pressure. A pressure sensor, located inside one of the five stock tanks, continuously monitors the tank operating pressure. This pressure reading was interpreted by the EVRU programmable logic controller (PLC), and used to control the two separate eductors.

The eductors are configured in a parallel orientation, and are designed to recover a total of 300 thousand standard cubic feet per day (Mscfd) or 208 standard cubic feet per minute (scfm) vent gas. Note that gas industry standard conditions are 60 degrees F, 14.7 psia. The primary eductor, with a capacity of 200 Mscfd (139 scfm), operates continuously to maintain tank pressures below 3.2 oz (0.20 psig). When a new inventory of condensate enters the tanks and the pressure begins to build up over 3.2 oz, a secondary eductor becomes operational. The secondary eductor, with a capacity of 100 Mscfd or 69 scfm, recovers gas to maintain the tank pressure to less than 4.8 oz (0.33 psig). It turns off automatically when the tank pressure drops below 1.6 oz (0.10 psig), and the primary eductor is the only unit operating. The design motive-to-vent gas ratio for the test site is approximately 5.2 scfm/scfm or 2.8 lb/lb. The EVRU eductors are controlled with the use of a PLC, which continuously monitors critical operating parameters. In the event the EVRU is unable to maintain the required tank pressure and the pressure begins to build up, some of the vent gas will escape through the PRVs to the atmosphere or flare.

1.4 PERFORMANCE VERIFICATION PARAMETERS

The verification test design was developed to evaluate EVRU performance. Prior to installation, all tank hatches were sealed and standard industry leak checks were performed by TFE operators to ensure the tanks and the entire gas piping network system was leak tight. The test strategy comprised of collection of a series of 1-minute averages of the motive gas flow rate, discharge gas flow rate, EVRU suction pressure, discharge gas temperature and pressure, and ambient conditions. The GHG Center's data acquisition system (DAS) recorded all continuously monitored performance data. Gas samples of the discharge and vent gas were collected throughout the test period, and sent to a laboratory for compositional and heating value analysis. Figure 1-3 illustrates the locations of all measurement instruments and gas sampling ports.

The specific verification parameters that were addressed during the field test are discussed below, along with the method of determination. The Test Plan provides detailed testing and analysis methods.

Gas Recovery Rate

Two independent flow meters were installed within the EVRU pipeline to measure the motive gas and EVRU discharge gas flow rates. Both meters were sized to measure the range of gas flow rates expected during normal operations at the test facility. Continuous flow measurements data were averaged in 1-minute time increments, and recorded for 8 days. The difference between the two flow readings represented the gas recovery rate of the EVRU as described in Equation 1.

$$Q_{recovered,i} = Q_{disch,i} - Q_{motive,i} \qquad \text{(Eqn. 1)}$$

Where:

$Q_{recovered,i}$ = Gas recovery rate for minute i, scfm
$Q_{disch,i}$ = Discharge gas flow rate for minute i, scfm
$Q_{motive,i}$ = Motive gas flow rate for minute i, scfm

Using the 1-minute gas recovery rates, a daily average gas recovery rate, was computed for each 24-hour measurement period. The overall average gas recovery rate, reported in units of thousand cubic feet per day (Mscfd) was computed, and represented the arithmetic average of the daily average gas recovery rates. The proportion of CH_4 and HAPS present in the recovered gas (measured by gas samples collected during testing) times the daily average recovery rate represented an estimate of the overall average recovery rates for these pollutants.

It was anticipated that the individual daily average gas recovery rates would be normally distributed and fall within a range of values (confidence interval) around the mean. After one week of testing, a 90 percent confidence interval for the daily average results was to be calculated. If the confidence interval was less than 30 percent of the overall average gas recovery rate, it would be concluded that no significant flow variability was present that would require further characterization, and testing would be terminated. Alternatively, if significant variability was observed and the confidence interval exceeded the set criteria, testing would be extended to a maximum of 28 days. As shown later in the results Section 2.0, the data completeness criteria were met after 8 days of testing was completed. The overall average for this time period is used to report the EVRU performance results.

The type of instrument used to measure motive gas flow rate was a Rosemount Model 3095 Integral orifice meter. This meter uses three different sensors (temperature sensor, differential pressure across an orifice, and absolute pressure) to measure mass flow rates, corrected to standard conditions, in units of scfm. Site specific natural gas composition, as measured immediately prior to testing, was programmed into the meter to enable real-time flow measurements. All components of the orifice meter assembly, including the sensors and orifice plate, were verified with NIST traceable standards, and met the accuracy and precision specifications. The entire orifice meter assembly was certified with an accuracy of ± 1.0 of reading by the manufacturer.

The type of instrument initially planned to be used for discharge gas flow measurements was an integral orifice meter, similar to the model used for motive gas flow rate. However after installation of the orifice meter, the pressure drop across the discharge line resulted in an over-pressurization of the entire EVRU system. The pressure increase was caused by a sudden contraction of the 4-inch discharge line into a 2-inch meter loop (Figure 1-4) which was used to house the orifice meter. Due to the negative disturbances caused on the operation of the EVRU, the orifice meter assembly was disabled, and an American Meter Company Model GTS-4 rotary turbine, already installed in the discharge line by TFE operators, was used to measure discharge gas flow. This arrangement represents a modification to the original Test Plan.

The turbine meter was calibrated with a NIST traceable volume prover prior to installation in the field, and was certified with an accuracy of ± 1.0 percent of reading. The turbine meter measures flow rates in units of actual cubic feet per minute (acfm). In order to calculate EVRU gas recovery rates (Equation 1), the turbine meter readings must be converted to standard conditions. This was accomplished by simultaneously measuring discharge gas temperature and pressure at the same time as discharge gas flow rates. The pressure measurements were performed with a Rosemount pressure transmitter, and the temperature measurements were performed with a Rosemount RTD. Both instruments were installed directly in the 4-inch discharge line according to the American Gas Association's (AGA) procedures for sensor location (AGA 1996).

Gas samples were collected from the vent gas stream (i.e., EVRU suction) and the EVRU discharge stream, and analyzed in accordance with American Society of Testing and Materials (ASTM) Method D1945 and Gas Processors Association (GPA) Method 2286 to determine concentrations of CH_4, non-CH_4 hydrocarbons (NMVOC), and BTEX (benzene, toluene, ethylbenzene, and xylenes) (ASTM 2001a). Gas density, compressibility and heating value analyses were performed according to ASTM Method 3588 (ASTM 2001b). The discharge gas heating values were used to assign an industry-accepted monetary value of the gas recovered and subsequently sold. Four gas samples from the discharge stream and four samples from the vent gas stream were collected during the test.

Annual Gas Savings and Emission Reductions

The 1-minute gas recovery rate measurements (discussed above) were also used to determine the total volume of gas recovered by the EVRU over the verification period. It was calculated as the integral of individual 1-minute flow measurements over the testing time (i.e., the area of a curve represented by flow rate and time). The total gas recovered during the verification period was reported in units of standard cubic feet (scf).

To estimate annual gas savings, the total gas recovered was extrapolated for a period of 1 year following the verification period. The host site operator was consulted, and it was determined that the oil production rate, EVRU operational availability, and other operating conditions that existed since the field testing would persist over the year. For this case, the total recovered gas was extrapolated to yield an annual estimated gas savings in units of standard cubic feet per year (scfy) as given in Equation 2:

$$Est.\ AGR = (TGR) + (Q_{recovered,overall\,avg})(No.\ Days\ Remaining\ In\ Year)\ (OA) \qquad \text{(Eqn. 2)}$$

Where:

Est. AGR	= Estimated annual gas recovered with the EVRU, scfy
$Q_{recovered,\,overall\,avg}$	= Overall average daily gas recovery rate, scfd
TGR	= Total gas recovered during testing, scf
OA	= EVRU operational availability, %

Annual gas savings is simply a comparison between the estimated annual gas recovered with the EVRU system and two baseline scenarios. The first baseline scenario assumes that no recovery system is in place, and the vent gas is simply released to the atmosphere. In this case, annual gas savings will be equal to the annual gas recovered. The second baseline scenario evaluates the annual gas savings for the test site (i.e., conventional VRU is used to recover vent gas). The GHG Center consulted with TFE operators to define the percent of time the VRU system was down. The annual gas savings for the test site is computed by multiplying the annual gas recovered times the percent down time. In this case, the use of the EVRU will eliminate the gas previously vented to the atmosphere during VRU downtime.

Annual emission reduction estimates for methane and HAPs were determined by multiplying the annual gas savings with the pollutant concentrations (determined from vent gas sample analysis). Emission estimates are reported as maximum potentital reductions, assuming all the recovered gas is vented directly to the atmosphere. Emission reduction estimates are also reported for the site condition, in which incremental savings, incurred during downtimes of conventional EVRU, are realized with the EVRU system.

Value of Recovered Gas

To estimate the cash value associated with the annual gas savings ($), the annual gas saved value, as determined above, was multiplied by site specific market price for the recovered gas. Consultations with the host site indicated that gas is currently valued at about $2.85 per million Btu (MMBtu). This price, multiplied by the lower heating value of the vent gas recovered, was used to compute the monetary value of the recovered gas.

Total Installed Cost

The capital and installation costs of the EVRU were verified for the test site. Capital costs were verified by obtaining cost data from COMM and TFE, and included all equipment and accessory items attributed to the installation. Labor hours associated with the installation, setup, and shakedown of the EVRU were also verified. The total installed cost reported is the sum of the capital equipment, accessory items, and labor costs. Costs associated with GHG Center measurements instruments are not included in this figure.

2.0 VERIFICATION RESULTS

2.1 TEST RESULTS

Installation, startup, and shakedown activities for the EVRU began on March 18, 2002, and were completed on March 22, 2002. The system was reported to be functioning properly by COMM on May 25. Verification testing occurred between June 23 and July 1, 2002, approximately 30 days after the EVRU began unattended operations.

During all test periods, the site's crude oil production proceeded normally. EVRU motive gas pressure exceeded specified set points during the first days of testing, which caused some operating inefficiency. Late in the test campaign, the discharge gas booster compressor failed for about 16 hours. The GHG Center did not include the data collected during that period in the analysis. Consequently, approximately 86 percent of all the collected data are considered valid and used here to report performance results.

The performance results for the verification parameters are reported as follows:

Section 2.2	Gas Recovery Rate
Section 2.3	Annual Gas Savings and Emission Reductions
Section 2.4	Value of Recovered Gas
Section 2.5	Total Installed Cost

2.2 GAS RECOVERY RATE

This section discusses the EVRU vent gas recovery rate, which is based on the difference between the discharge gas and motive gas flow rate measurements (Equation 1). All flow rates in this section have been standardized for temperature (60 °F), pressure (14.73 psia), and gas compressibility factor (as required).

Table 2-1 shows the daily average discharge gas, motive gas, and vent gas flow rates. The overall average vent gas recovery rate was 175 Mscfd for the testing period. Table 2-1 also presents the calculated variability and confidence interval of the flow rate measurements. Based on the Test Plan, it was expected that 90 percent of the individual daily average recovery rates would be within 0.30 times (30 percent) of the overall average recovery rate or about 52 Mscfd. In essence, this was the maximum variability allowed in the dataset to report EVRU performance results. The actual testing duration lasted a total of 8 days, with over 85 percent of the 1-minute test data defined as valid measurements. The 90 percent confidence interval half width for the overall average vent gas recovery rate during this period was 25 Mscfd, which indicates that the overall average recovery rate for the site during any given day will fall within a range of 150 to 200 Mscfd.

The daily average motive gas required to recover the vent gas varied between 635 and 775 Mscfd. The overall average motive-to-vent gas volume ratio during the test period was 4.2 scfm/scfm (or 2.2 lb/lb) , and ranged from a low of 3.1 to a high of 6.7 scfm/scfm. The overall average ratio is slightly less than the 5.2 (by volume) or 2.8 (by mass) design ratio reported by COMM.

The higher motive-to-vent gas ratio, often exceeding 10 scfm/scfm, was largely influenced by the lack of control of the motive gas pressure during the first 3 days of the testing period. On June 26, COMM installed an alternate controller (Proportional Plus Reset Controller by Fisher) to better control the motive gas pressure. The new controller contained two capillaries which were connected to the high pressure supply side (~1050 psig) and the motive gas side, each located upstream and downstream of the pressure regulator, respectively. The controller senses the two pressures, and adjusts the regulator to maintain 850 psig pressure on the downstream side. Once the motive gas pressure was stabilized to 850 psig, the overall average motive-to-vent gas volume ratio decreased to approximately 3.8 scfm/scfm. Performance trends associated with these conditions are discussed in the following subsections.

Table 2-1. Summary of Test Results

Test Day			Oil Production Rate (bbl/day)	Daily Average Flow Rate			Average Motive-to-Vent Gas Ratio (scfm/scfm)	Vent Gas:Oil Production Ratio (scf/bbl)
Day	**Time Period**	**Number Of Valid 1-minute Data**		**Discharge Gas (scfd)**	**Motive Gas (scfd)**	**Vent Gas (scfd)**		
6/23-24/02	2 PM - 2 PM	1,408	1,067	928,663	760,881	167,744	4.5	157
6/24-25/02	2 PM - 2 PM	1,262	984	834,197	684,126	150,778	4.5	153
6/25-26/02	2 PM - 2 PM	1,395	961	809,994	689,709	120,866	5.7	126
6/26-27/02	2 PM - 2 PM	1,146	1,051	931,306	710,436	220,720	3.2	210
6/27-28/02	2 PM - 2 PM	1,416	920	921,849	698,739	223,933	3.1	243
6/28-29/02	2 PM - 2 PM	1,400	1,019	923,278	719,022	204,395	3.5	201
6/29-30/02	2 PM – 2 PM	710	1,002	924,935	774,633	150,308	5.2	150
6/30-7/1/02	2 PM – 8 AM	1,061	925	794,850	634,535	160,095	4.0	173
Cumulative		9,798	7,928	7,069,072 scf	5,672,080 scf	1,398,838 scf		
Average		1,225	991	883,634	709,010	174,855	4.2	177
Std. Deviation		248	54	59,507	44,309	37,322	0.9	39
90% Confidence Interval				39,869	29,686	25,005		

2.2.1 EVRU Performance Trends

Table 2-2 provides a summary of the operating conditions encountered during the test period. This data and the 1-minute average measurements data were used to identify potential trends and relationships between vent gas recovery rate and oil production rate, ambient temperature, motive gas pressure, EVRU suction pressure, and motive gas flow rate.

Figure 2-1 shows the relationship between the daily average vent gas recovery rate and the daily total oil production levels. The oil production levels and the gas/oil separator pressures were relatively consistent throughout the test period. A direct relationship between oil production rate and the vent gas recovery rate was expected given that an increase in oil production should lead to more generation of vent gas and hence additional vent gas to be recovered. However, such trends were not observed with a limited dataset, and the variability in gas recovery rate was primarily due more to the operation of EVRU and not the site operating conditions. On average, approximately 177 ± 39 Mcf vent gas was recovered per barrel of oil processed at the test site.

Table 2-2. Summary of Daily Operational Conditions

Day	Oil Production Rate (bbl/day)	Discharge Gas Pressure (psia)	EVRU Suction Pressure (psig)	Seperator Pressure (psia)	Ambient Temp (°F)	Discharge Gas Temp (°F)	Vent Gas Temp (° F)
6/23-24/02	1,067	37.59	-0.056	-	83.38	59.97	89.36
6/24-25/02	984	37.67	0.014	-	86.07	64.44	90.59
6/25-26/02	961	37.60	0.089	72	86.58	63.99	90.20
6/26-27/02	1,051	37.80	-0.317	-	84.80	69.51	89.77
6/27-28/02	920	37.52	-0.353	72	85.76	70.19	88.72
6/28-29/02	1,019	37.83	-0.240	-	77.21	62.50	85.33
6/29-30/02	1,002	37.90	0.006	-	79.26	58.36	81.86
6/30-7/1/02	925	37.07	-0.112	72	78.73	60.24	80.43
Average	991	37.62	-0.121	72	82.72	63.65	87.03
Std Dev	54.10	0.26	0.164	0	3.75	4.35	3.99

Figure 2-1 shows the relationship between the daily average vent gas recovery rate and the daily total oil production levels. The oil production levels and the gas/oil separator pressures were relatively consistent throughout the test period. A direct relationship between oil production rate and the vent gas recovery rate was expected given that an increase in oil production should lead to more generation of vent gas and hence additional vent gas to be recovered. However, such trends were not observed with a limited dataset, and the variability in gas recovery rate was primarily due more to the operation of EVRU and not the site operating conditions. On average, approximately 177 ± 39 Mcf vent gas was recovered per barrel of oil processed at the test site.

Figure 2-1. Relationship Between Vent Gas Recovery Rate and Oil Production Rate

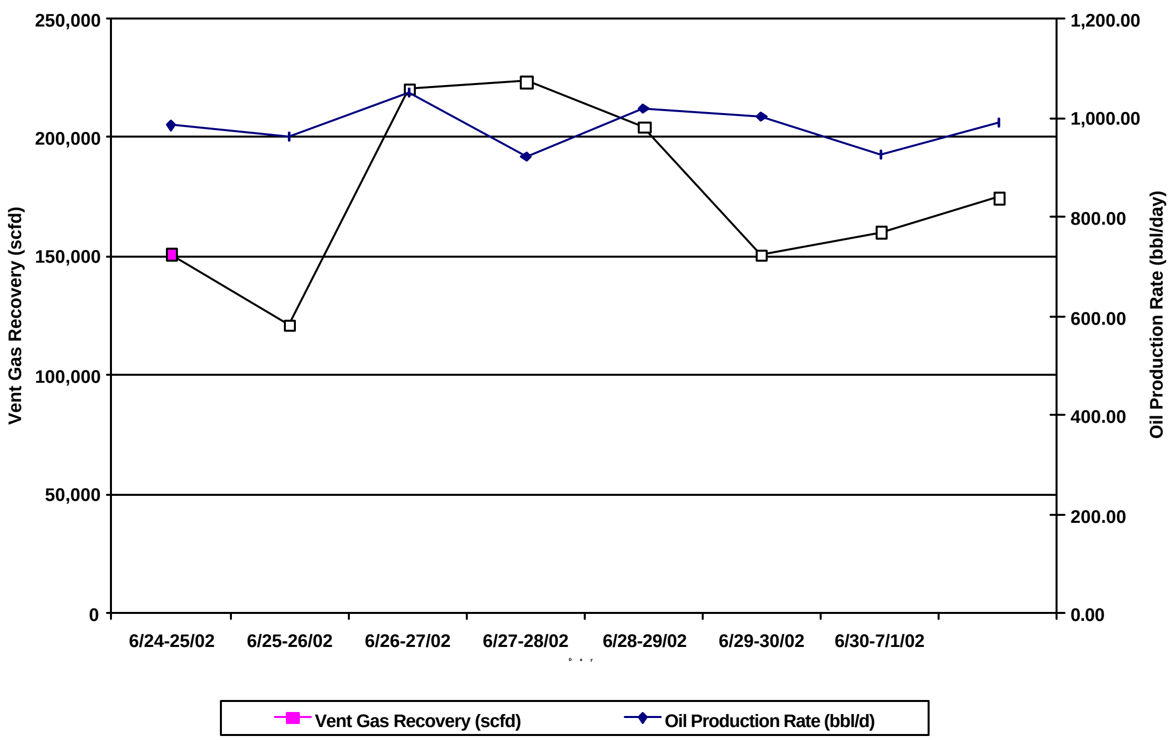


Figure 2-2 shows a plot of the vent gas recovery rate as a function of ambient temperature for June 24. As shown in this dataset and similar trends observed for other testing days, the highest vent gas recovery period corresponds to the highest daily temperature period. This is consistent with increase in flash gas and working losses expected at elevated ambient temperatures. The data also show that the EVRU is capable of accommodating typical daily variations in vent gas volumes.

Figure 2-3 shows time series plots of motive gas flow rate, vent gas recovery rate, and EVRU suction pressure. In the initial days of testing, the motive gas pressure was significantly higher than the 850 psig design pressure. This operating condition increased the EVRU suction pressures to greater than 0.2 psig, and resulted in lower volume of recovered gas. It is expected that during these high pressure conditons, the entire EVRU piping network became overpressurized, and may have caused the tank pressures to exceed the setpoint. Under these conditions, it is likely that the gas uncollected by the EVRU may have escaped through the PRVs.

Figure 2-2. Relationship Between Vent Gas Recovery Rate and Ambient Temperature 6/24/2002

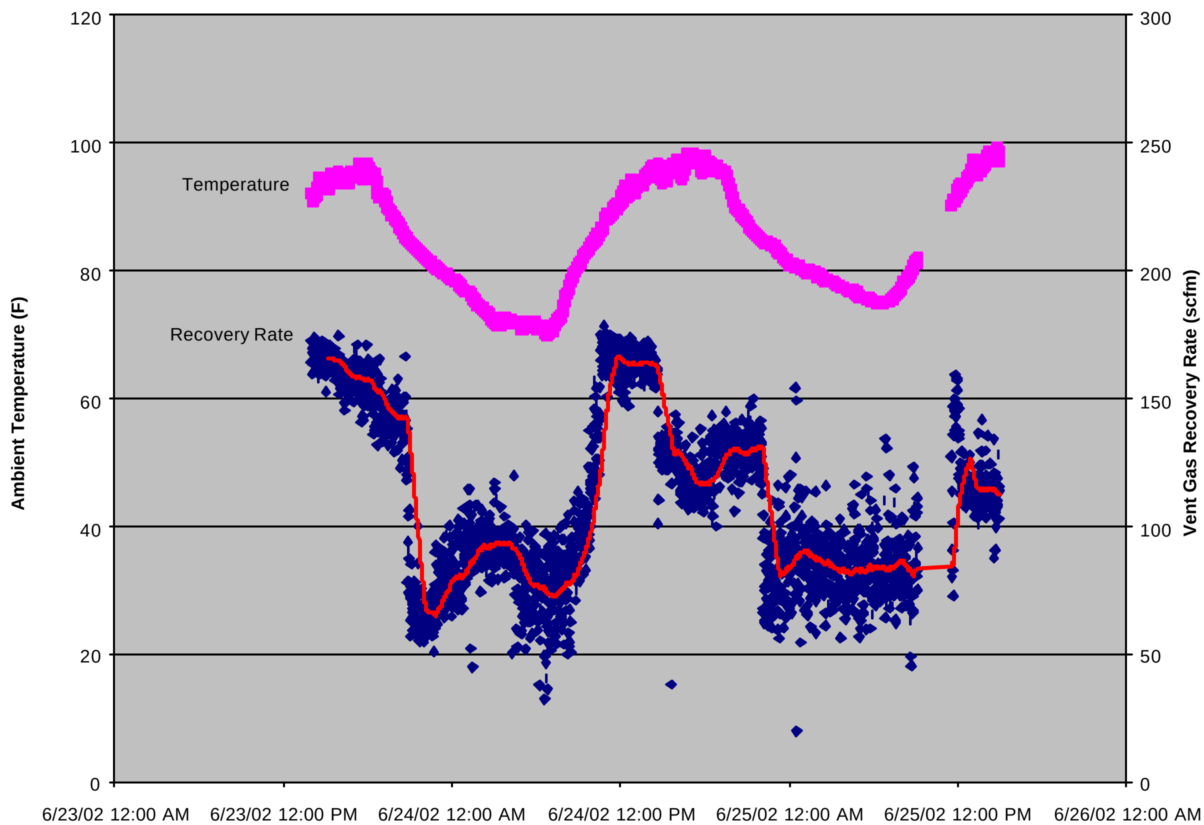
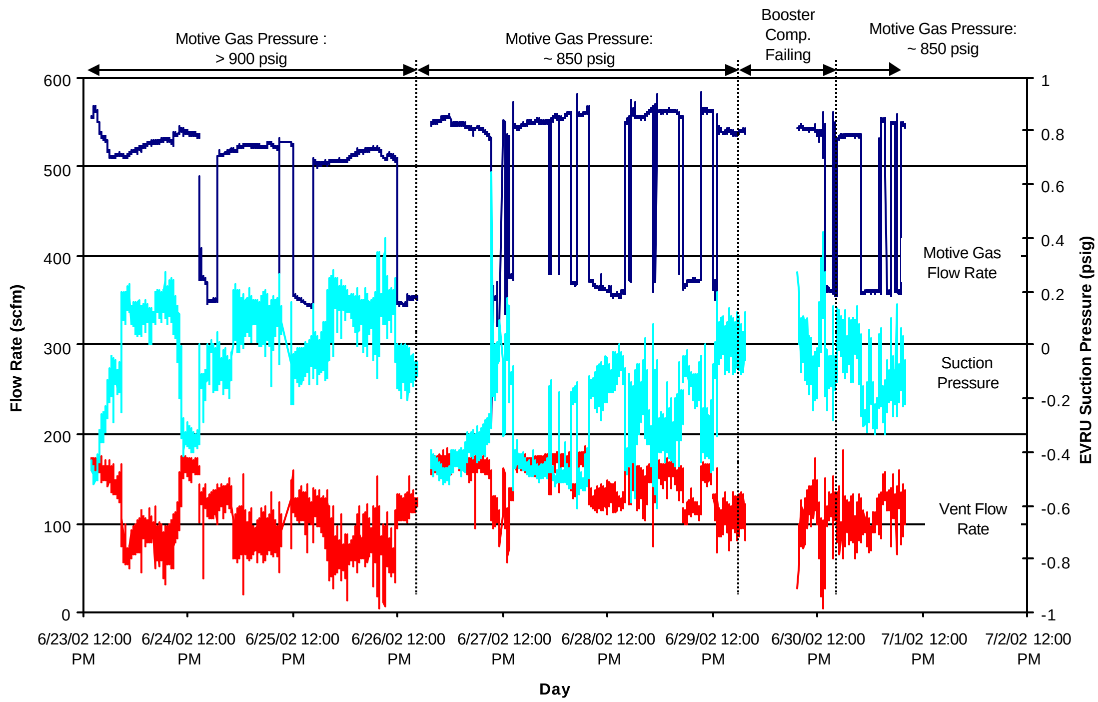


Figure 2-4 shows the relationship between the motive-to-vent gas ratio as a function of vent gas pressure, and Figure 2-5 shows a similar plot, except that the vent gas recovery rate is shown as a function of EVRU suction pressures. The data in these figures are based on 1-minute measurements data collected during the +900 psig motive gas pressure condition, and after the motive gas pressure was stabilized to 850 psig. The figures show that there is a systematic relationship between the EVRU suction pressure, gas recovery rate, and motive gas flow rate. The relationship also depends upon whether the primary eductor operates alone or in conjunction with the secondary eductor. Note that the secondary eductor never operated alone during the tests.

Figure 2-3. Time Series Plots of Key Performance Data

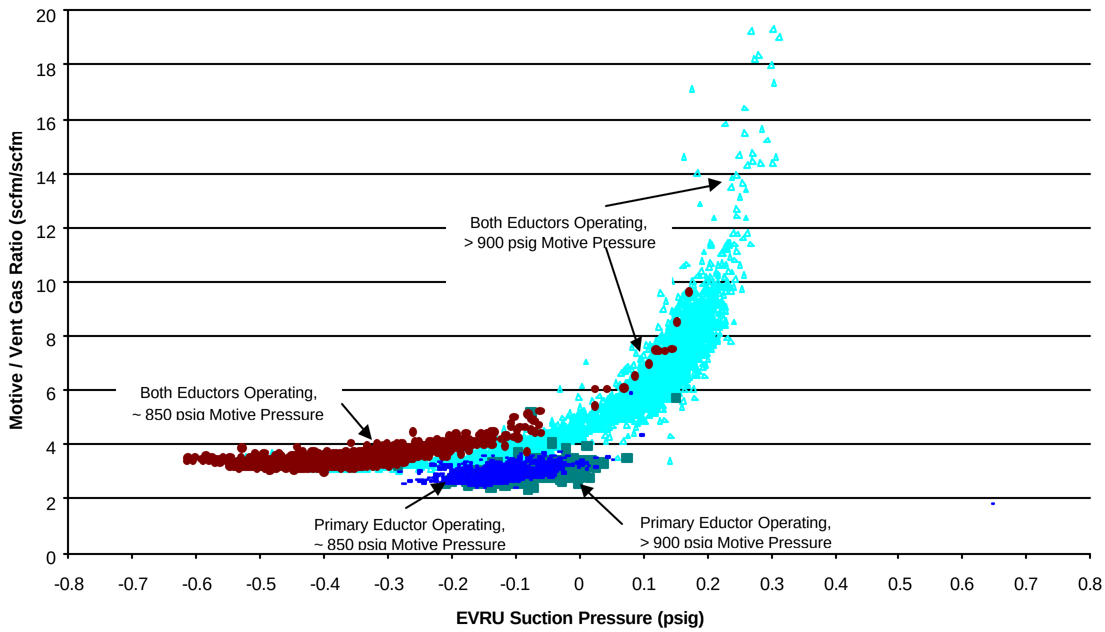


At the 850 psig condition, motive gas flows generally varied between 350-380 scfm with one eductor operational and 530-565 scfm with both units operating. The EVRU recovered between 100 and 140 scfm gas with the primary eductor operating, and between 140 and 180 scfm with both eductors operating. These recovery capacities are consistent with the design values described in Section 1.3. It is concluded that when the system is operating at design motive gas pressures, the vent gas recovery rate is consistent with design flow capacities, and clearly responsive (by about 30 scfm; Figure 2-4) to the cycling of the second eductor unit. The average motive-to-vent gas ratio was 3.2 scfm/scfm with one eductor operating, and 3.5 scfm/scfm with two eductors operating.

At the 950 psig condition, the motive gas flow rate generally varied between 340-350 scfm with one eductor operational and 500-530 scfm with both eductors operating. With the primary eductor operating, the motive-to-vent gas ratio was 3.2 scfm/scfm (similar to the 850 psig condition). However, when both eductors are in operation, the motive-to-vent gas ratio increases dramatically to 6.1 scfm/scfm, which equates to significantly less gas to be recovered. In this case, the gas recovery rate was relatively low and variable. Based on these observations, it is clear that at higher motive gas pressures, the system is unable to recover the volume ratio of vent gas. Eventually, the system is unable to perform as designed, and the EVRU suction pressure, which is directly related to the tank pressure, begins to build up and pressurize the entire piping network. The verification test revealed that continuous and proper control of the motive gas pressure is essential to achieving best performance from the EVRU system.

Although this verification did not address long-term EVRU reliability, failure of external devices such as the booster compressor (Figure 2-3) may have more impact than failure of EVRU components. The eductors themselves have no moving parts. The other active components, such as pressure sensors and control valve actuators, are well-accepted designs whose operating reliability data would be available from their manufacturers.

Figure 2-4. Motive-to-Vent Gas Ratio vs. EVRU Suction Pressure



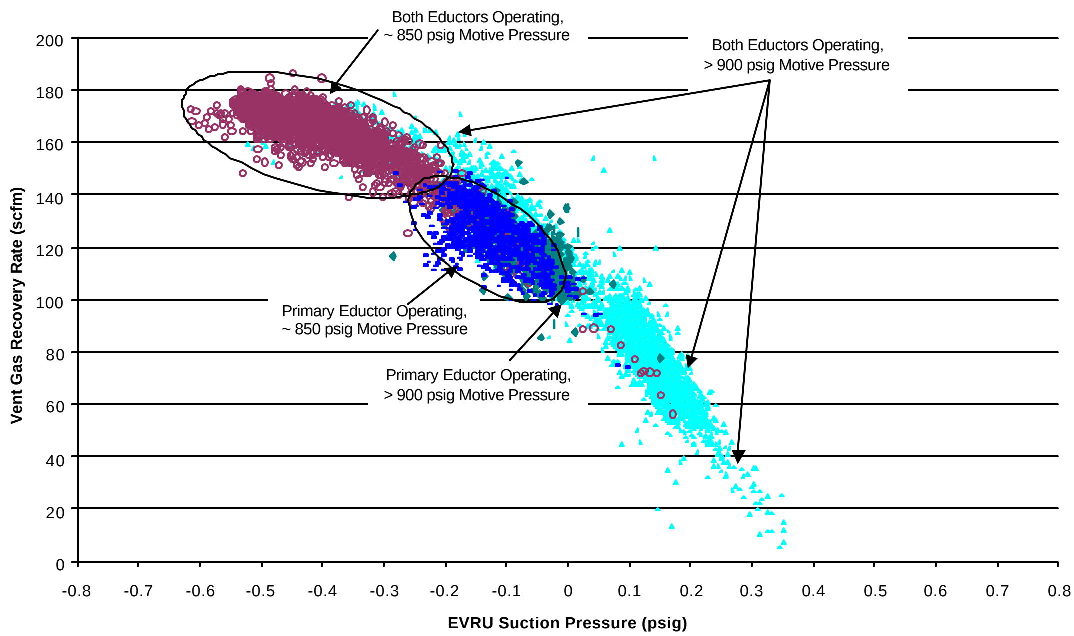
Finally, as discussed previously, the EVRU is designed to maintain a slightly negative pressure on the suction side (-0.5 and 0.0 psig). The data show that the maximum volume of gas can be recovered when the suction pressures are maintained at this level. Over 70 percent of the data were within the optimum vent gas pressure range, accounting for over 80 percent of the vent gas recovered.

Primary eductor operations comprised 25 percent of the collected data and accounted for 25 percent of the vent gas recovered. The remaining 75 percent of the collected data (and vent gas recovered) was due to both eductors operating together.

2.2.2 Vent Gas Composition and Air Pollutant Recovery Rate

Vent gas compositional analysis was conducted on gas samples collected from the EVRU suction line to determine methane, BTEX, and total HAP concentrations. A total of four vent gas samples were collected during the test period. Each of these samples showed an unusually high concentration of nitrogen and oxygen. For these four samples, the oxygen averaged 3.17 mole percent and the nitrogen averaged 14.5 mole percent (Appendix C). Such concentrations were unexpected, as vent gas must be free of air to avoid explosive conditions. The data were compared to the preliminary vent gas data taken prior to the start of the test period (Appendix B), and it showed that vent gas should have no oxygen and a very low concentration of nitrogen. This is supported by the fact that the EVRU contains an oxygen alarm which shuts down the system if concentrations exceed 2.5 percent. No shutdowns due to oxygen exceedances occurred during the tests.

Figure 2-5. Gas Recovery Rate vs. EVRU Suction Pressure



During testing, it is likely that air contaminated the vent gas samples. This is indicated by the oxygen and nitrogen content in some of the samples as analyzed. The Test Plan specified that the field personnel would close the sample cylinder valve while a partial vacuum remained in the cylinder. The laboratory recommended this practice to minimize the possibility that heavy hydrocarbons might condense in the cylinder. The GHG Center suspects that the partial vacuum was responsible for air in-leakage while the valves were being operated. This could also have occurred while the test operator was disconnecting the cylinder from the sampling port or during transport. The GHG Center hasn't had this problem in the past when the cylinders were left at elevated pressures.

Ultimately, the contamination source cannot be confirmed. The GHG Center received the lab results after the field campaign had concluded, so re-sampling was not an option. Consultation with the laboratory and site operators indicate that such contamination is relatively common. It is standard industry practice to normalize the concentrations to expected nitrogen levels in these situations. Appendix C provides the raw and normalized vent gas analyses based on the nitrogen (and oxygen) concentrations of the preliminary vent gas data.

The average normalized vent gas compositions over the course of the testing period are shown in Table 2-3. For each compound, the mole percent, mole fraction, and weight percent are given. These data are used to report daily average methane, BTEX, and HAP recovery rates in volume and mass basis.

Table 2-3. Normalized Average Vent Gas Composition [a]				
Component	**Mole Percent**	**Weight Percent**	**Volumetric Flow Rate (Mscfd)**	**Mass Flow Rate (lb/hr)**
Nitrogen	0.06	0.05	0.11	0.34
Oxygen	0.00	0.000	0.00	0.00
Carbon Dioxide	0.25	0.31	0.44	2.14
Methane	**50.25**	**22.09**	**87.86**	**154.72**
Ethane	10.33	8.51	18.06	59.61
Propane	11.70	14.14	20.46	99.02
Isobutane	5.62	8.95	9.83	62.69
n-Butane	6.17	9.83	10.79	68.83
Isopentane	3.59	7.09	6.28	49.71
n-Pentane	2.62	5.18	4.58	36.28
Hexanes Plus	9.41	23.85	16.45	167.03
TOTAL	**100.00**	**100.00**	**174.86**	**700.37**
Benzene	0.579	1.239	1.01	8.68
Toluene	0.424	1.071	0.74	7.50
EthylBenzene	0.034	0.099	0.06	0.69
Xylenes (Total)	0.082	0.239	0.14	1.67
BTEX	**1.119**	**2.648**	**1.96**	**18.54**
n-Hexane	1.161	2.742	2.03	19.20
C9 Naphalenes	0.111	0.350	0.19	2.45
HAPS	**2.390**	**5.740**	**4.18**	**40.19**
Higher Heating Value	2089 Btu/ft^3			
Lower Heating Value	1919 Btu/ft^3			

[a] Represents average results of four samples collected, see Appendix C. Average total mass flow was 16,809 lb/day or 700.3 lb/hr; average total volumetric flow was 174.855 Mscfd; average total molecular weight was 36.49 lb/lb
[b] BTEX compounds are benzene, toluene, ethyl benzene, and xylenes
[c] HAP compounds include the BTEX compounds, n-hexane, and C9 Naphthenes, as defined in 40 CFR Park 63

2.3 ANNUAL GAS SAVINGS AND EMISSION REDUCTIONS

Annual gas savings represent an estimate of the total volume of gas that can be recovered with the EVRU system in one year. As discussed in Section 1.4, the computation for this verification parameter requires assigning an operational availability to the EVRU.

The GHG Center has verified that during the test period, the EVRU operated continuously with the exception of 4.3 hours required to replace the original motive gas pressure regulator. The downtime related to the failure in the booster compressor (about 14.8 hours) is unrelated to the performance of the EVRU, and is not used to estimate EVRU operational availability. At the time of writing this report, approximately 5 months had elapsed since the test was completed. During this time, the EVRU had logged no downtime, and according to the TFE operators, the system thus far has been "maintenance free". Based on this information and the data collected during the verification period, the operational availability of the EVRU system for the first 5 months of operation is computed to be 99.91 percent. It is assumed that this availability is likely to persist throughout the year, as the EVRU contains few moving parts which would wear out and require maintenance. Consequently, the annual gas recovered value is computed as follows in Equation 3:

$$\text{Est. AGR} = TGR_{\text{EVRU operating}} + TGR_{\text{booster comp. down}} + Q_{\text{recovered, overall avg}}\,(OA)\,(Days) \qquad \text{(Eqn. 3)}$$

$$TGR_{\text{booster comp. down}} = Q_{\text{recovered, overall avg}}\,(OA)\,(BDT)$$

Where:

Est. AGR = Estimated annual gas recovered with the EVRU, scfy
$TGR_{\text{EVRU operating}}$ = Total gas recovered while EVRU operating, scf
$TGR_{\text{booster comp. down}}$ = Total gas that could be recovered if the booster compressor was operating, scf
$Q_{\text{recovered, overall avg}}$ = Overall daily average vent gas recovery rate, scfd
OA = Estimated EVRU operational availability, 99.91 %
Days = Number of days remaining in year, 357 days
BDT = Total time the booster compressor was not operating, 0.6 days

For estimation purposes, the above calculation reimburses the gas lost during booster compressor downtimes. Annual gas savings is computed as the difference between the annual gas recovered with the EVRU and the gas recovered with two baseline management practices. In the first baseline scenario, it is assumed that no recovery system is in place, and all of the vent gas would be released to the atmosphere. The second baseline scenario represents the test site. According to TFE operators, the existing VRU system was not operational approximately 10 percent of the time (876 hrs/yr). When this VRU was down, uncollected gas was simply vented to the atmosphere. Therefore, use of the EVRU will eliminate those emissions previously vented to the atmosphere during VRU downtime. Annual gas savings for the test site is simply the total gas recovered with the EVRU times 0.10. The following discussion summarizes the results.

It is estimated that 63.9 million standard cubic feet per year (MMscfy) gas can be recovered with the EVRU. For a site that vents gas directly to the atmosphere, annual gas savings will also be 63.9 MMscfy. For the test site, whose operational availability of the conventional VRU system is 90 percent, the annual gas savings are much lower (6.4 MMscfy). The GHG Center recognizes that some sites which employ conventional VRUs may experience fewer downtimes than the test site. For such facilities, replacement of the VRU with EVRU may not result in significant gas savings.

Table 2-4 summarizes the annual emission reduction estimates for the two baseline scenarios. These results were computed by multiplying the annual gas savings estimate (described above) with methane and HAP concentration levels. Annual emission reduction for other hydrocarbons is also presented.

Table 2-4. Annual Emission Reduction Estimates				
	Baseline Recovery System			
	Vent Gas Is Released to Atmosphere		Test Site: Conventional VRU With a Gas Compressor is Used (operational availability = 90 %)	
	MMscfy	Tpy	MMscfy	Tpy
Methane	32.1	678	3.2	67.8
HAPs	1.5	176	0.2	17.6
Other Hydrocarbons	30.1	2,203	3.0	220.3

2.4 VALUE OF RECOVERED GAS

Industry standard practice is to value the gas in terms of price per million BTU (MMBtu) heat content. This allows consistent billing over a range of gas blends. The normalized, average lower heating value (LHV) of the vent gas was 1919 BTU/scf. At the average daily vent gas production rate of 174,855 scfd, this would amount to 3.35×10^8 Btu/day, or 335 MMBtu/day. TFE valued the host site's gas at an average $2.85 per MMBtu for the various gas blends it supplied to customers during June, 2002. This means that the vent gas would be valued at $956 per day, or $349,318 per year at that production rate with the measured LHV.

For reference, Appendix D provides the pre-test discharge gas composition. Appendix E shows the composition during the test campaign. Similar to the vent gas samples, the test run discharge gas samples were contaminated with air. When the contaminated gas samples are normalized to average oxygen and nitrogen content as seen in the pre-test samples, carbon compound concentrations and heating values are consistent for a gas mixture containing approximately 3.2 parts natural gas to 1 part vent gas by volume.

2.5 EVRU TOTAL INSTALLED COST

The capital costs and total installed costs of the EVRU system are presented in Table 2-5. These costs reflect the total costs required for the installation and configuration of the system installed at the TFE-El Ebanito site. Costs associated with the GHG Center measurement instruments are not included in these estimates.

Capital cost items include engineering design of the EVRU system, EVRU fabrication, motive gas and spool fabrication, commissioning and startup, and equipment transportation and delivery to the site. Installation costs associated with fabrication, start-up, and shakedown activities are also detailed in the table.

The total installed costs for the EVRU are estimated to be $107,958. As previously discussed, the value of the recovered gas is $349,318. The EVRU has operated at the host site maintenance-free for about 6 months. Given this, a simple payback period of 0.3 years is estimated for a site without a currently installed VRU. If an existing VRU is on site, payback would be much higher, and would need to account for potential maintenance expenses for the VRU.

Table 2-5. Total Installed Costs for the EVRU System at the TFE Site

Item					**Costs ($)**
Engineering design of EVRU					8,000
EVRU Fabrication (including labor and materials)					49,160
Motive Gas Spool Fabrication & Misc. (COMM)					2,500
Commissioning and startup					8,450
Equipment transportation and delivery					1,400
Total EVRU Capital Costs					**69,510**
Summary of EVRU Installation Costs					
Date	**Activity**	**Labor (man-hrs)**	**Hourly Rate ($)**	**Labor Costs ($)**	**Materials Costs ($)**
5/13/2002	Digging out 6-inch line from tank battery to EVRU	100	32	3,200	2,770
5/14/2002	Fabrication work, digging out 6-inch line from tank battery to EVRU	100	32	3,200	0
5/15/2002	Install 6-inch replacement section, continue fabrication, set EVRU in place	100	33	3,300	1,020
5/16/2002	Installation and connections for EVRU	100	33	3,300	0
5/17/2002	Install flowline and hookup to EVRU and tank battery, install makeup gas to tanks, install controller and blowcase	195	28	5,550	3,500
5/18/2002	Finish installation of EVRU, back fill ditches, start up EVRU	80	36	2,850	0
5/20/2002	Equipment costs	0	0	0	2,891
6/11, 6/13, and 6/19/02	Painting, backfilling, and finishing work	71	24	1,683	0
6/20 and 6/21/02	Install blowcases on EVRU suction and tank battery	140	28	3,884	0
6/22/2002	Painting, backfilling, and finishing work	42	31	1,300	0
Total Labor and Materials Installation Costs		**928**	na	**28,267**	**10,181**
Total Cost of EVRU System Installed and Commissioned at TotalFinaElf Facility					**107,958**

Note: Labor rates vary widely depending on personnel used including laborers, mechanics, welders, heavy machine operators, etc. Values represented here are average rates for personnel involved in installation during a particular day.

Installation materials cost consists mainly of fabrication piping, fittings, valves, controllers, and two blowcases.

3.0 DATA QUALITY ASSESSMENT

3.1 DATA QUALITY OBJECTIVES

For verifications conducted by the GHG Center, measurement methodologies and instruments are selected to ensure that a stated level of data quality occurs in the final results. Data quality objectives (DQOs) are specified for key verification parameters before testing commences. These objectives must be achieved in order to draw conclusions with the desired level of confidence.

The process of establishing DQOs starts with identifying the measurement variables that affect the verification parameter. The errors associated with each measurement variable must be accounted for to determine their cumulative effect on the data quality of each verification parameter. For example, determination of the gas recovery rate parameter requires measurement of discharge gas flow rate and motive gas flow rate. Thus, the error in gas recovery rate value is affected by the performance of the turbine and the orifice flow meters. The measurement errors for instruments are stated in terms of accuracy, precision, and completeness, and are defined as Data Quality Indicator (DQI) goals. Achievement of each DQI goal ensures that DQOs for each verification parameter are satisfied.

Table 3-1 presents the DQOs for the verification parameters, the actual error achieved, and the method of reconciliation. Table 3-2 summarizes the measurment (i.e., DQI) goals and the actual errors achieved. Table 3-3 summarizes the QA/QC activities that were performed to reconcile the DQOs and DQIs. The reconciliation process consisted of:

- Performing independent performance checks in the field with certified reference materials
- Following approved reference methods
- Factory calibrating the instruments with NIST traceable standards prior to use
- Conducting sensor diagnostics in the field to ensure that the instruments are installed and operated correctly

The following discussion illustrates that most DQI goals were achieved, and for all of the verification parameters, the DQOs were met. Further discussion of these data quality results is provided below.

Table 3-1. Data Quality Objectives			
Objective	**Required**	**Achieved**	**Method of Reconciliation**
Gas Recovery Rate	± 20 %	± 9.68 %	Error propagation of motive gas flow rate, discharge gas flow rate, discharge gas temperature, and discharge gas pressure measurements
Duration of Testing	At least 1 week of testing having 90% of daily average gas recovery rates within 0.30 times the overall average gas recovery rate OR a maximum of 28 days of testing	8 Days	Calculation of 90% confidence interval using the average daily gas recovery rates.
Annual Gas Savings	± 20 %	± 9.68 %	Error propagation of motive gas flow rate, discharge gas flow rate, discharge gas temperature, and discharge gas pressure measurements
Emission Reductions	Not specified	± 9.74 %	Error propogation of gas recovery rate and methane concentration measurements
Value of Gas Recovered	± 20 %	± 9.68 %	Error propagation of motive gas flow rate, discharge gas flow rate, discharge gas temperature, and discharge gas pressure measurements and LHV analysis.

Table 3-2. Measurement Instrument Specifications and Data Quality Indicator Goals									
Site Measurements					**Accuracy**			**Completeness**	
Measurement Variable		**Instrument Type / Manufacturer**	**Instrument Range**	**Range Observed in Field**	**Goal**	**Actual**	**How Verified / Determined**	**Goal**	**Actual**
Motive Gas	Standard Gas Flow Rate	Integral Orifice Meter/ Rosemount 3095	200 to 600 scfm	210 to 584 scfm	± 1.0 % reading	± 1.92 % reading	3 point calibration of static pressure, differntial pressure, and temperature sensors Flow through comparison check with turbine meter	90% of daily 1-minute measurements data must be valid	86% of possible 1-minute data were valid
Vent Gas	Vent Gas Temperature	Type K Thermocouple / Omega	0 to 200 ^{o}F	20 to 96 ^{o}F	± 0.10 % reading	± 1.3 % reading	8 point calibration check with reference standard	90% of daily 1-minute measurements data must be valid	86% of possible 1-minute data were valid
	EVRU Suction Pressure	Pressure Transmitter / Rosemount 3051	-50 to 50 in. H_2O	-17 to 18 in. H_2O	± 0.08 % reading	± 0.036 % reading	5 point calibration check with reference standard		

(continued)

Table 3-2. Measurement Instrument Specifications and Data Quality Indicator Goals (continued)

Site Measurements					Accuracy			Completeness	
Measurement Variable		**Instrument Type / Manufacturer**	**Instrument Range**	**Range Observed in Field**	**Goal**	**Actual**	**How Verified / Determined**	**Goal**	**Actual**
Discharge Gas	Actual Gas Flow Rate	Rotary Turbine Gas Meter / American Gas Meter Co. GTS-4	0 to 300 acfm	147 to 291 acfm	± 1.5 % reading	± 0.30 % reading	5 point calibration check with reference standard	90% of daily 1-minute measurements data must be valid	86% of possible 1-minute data were valid
	Gas Pressure	Integral Orifice Meter/ Rosemount 3095 absolute pressure sensor	0 to 800 psia	32.89 to 38.86 psia	Not specified	± 0.023 % FS	4 point calibration check with reference standard		
	Gas Temperature	Integral Orifice Meter/ Rosemount 3095 temperature sensor	-40 to 1200 ^oF	40 to 84 ^oF	Not specified	± 0.006 % FS	4 point calibration check with reference standard		
Vent and Discharge Gas Sampling	Component concentrations	Gas Chromatograph / HP 589011	0 to 100 % for each component	Discharge methane ranged from 68 to 84 %	± 3.0 % error ASTM D1945 Repeatability Specifications (see Test Plan)	± 0.61 % average error, ± 0.64 % average repeatability	Comparison with certified audit concentration and Duplicate analysis of audit sample	Minimum 3 valid gas samples per week	4 discharge gas samples and 4 vent gas samples were collected including 1 audit sample from each location. The laboratory normalized air-contaminated samples to zero O_2 and expected N_2 values
	Lower Heating Value	Calculated using composition analysis	not applicable	Discharge methane ranged from 68 to 84 %	± 0.2 %	± 0.61 %	Average difference between audit gas reference concentration and measured concentration		
Ambient Meteorological Conditions	Ambient Temperature	Vaisala Model HMD 60UO/YO transmitter	-40 to 140 ^oF	± 0.9 ^oF	± 0.9 ^oF	± 0.13 ^oF	1 point calibration check with reference standard	95% of daily 1-minute measurements data must be valid	89% of possible 1-minute data were valid

Table 3-3. Summary of QA/QC Checks				
Measurement Variable	**QA/QC Check**	**Frequency**	**Expected or Allowable Result**	**Results Achieved**
Discharge Gas Flow Rate	Turbine flow meter calibration by manufacturer *	Beginning of test	± 1.5 % reading	± 0.30 % reading
	Pressure sensor calibration by manufacturer	Beginning of test	Not specified	± 0.023 % FS
	Temperature sensor calibration by manufacturer	Beginning of test	Not specified	± 0.006 % FS
Motive Gas Flow Rate	Calibration of absolute pressure sensor, differential pressure sensor, and temperature sensor by manufacturer	Beginning of test	± 1.0 % reading	± 1.0 % reading
	Field verification – flow through comparison test with turbine meter*	During Test	Percent difference between orifice meter and turbine meter should be less than ± 1.5 %	± 1.92% reading
	Sensor diagnostics	Beginning and end of test	Pass	Passed all sensor diagnostic checks
Vent and Discharge Gas Composition	Independent performance check with blind audit sample*	Two times during test period	± 3.0 % for each target gas constituent	Overall average ± 0.61 % (See Section 3.2.2)
	Duplicate analysis performed by laboratory *	At least twice during test period and on one blind audit sample	Analysis values should be within ASTM D1945 repeatability specifications	Overall average ± 0.64 % (See Section 3.2.2)
	Confirm canister is fully evacuated	Before collection of every sample	Canister pressure < 1 psia	All sample canisters used < 1 psia
	Calibration with gas standards by laboratory	Prior to analysis of each lot of samples	± 1.0 % for each gas constituent (C1 - C12)	See Table 3-5
Ambient Meteorological Conditions	Instrument calibration by manufacturer *	Beginning of test	Temperature: ± 0.9 °F	Temperature: ± 0.13 °F
	Reasonableness checks	At least once during test period	Recording should be comparable with portable humidity and temperature sensor	Recording comparable with portable temperature sensor
Vent Gas Temperature	Instrument calibration by EPA with NIST traceable standard*	Beginning of test	± 0.10 % reading	± 1.3 % FS
EVRU Suction Pressure	Instrument calibration by manufacturer *	Beginning of test	± 0.08 % reading	± 0.036 % reading
	Reasonableness checks	Throughout test	Readings should be less than 0.3 psig on vent gas and approximately 40 psia on discharge gas	Most readings were within specified range for vent gas. All readings were within specified range for discharge gas
* Results of these QA/QC checks are used to reconcile data quality indicators				

3.2 RECONCILIATION OF DQOS AND DQIS

Table 3-2 summarizes the range of measurements observed during the verification test and the completeness goals and completeness achieved. Completeness is defined as the number of valid data points expressed as a percentage of the total number of readings possible during the data collection day. The completeness goals for the verification test were to collect 90 percent of the 1-minute averages for the flow measurement variables, collect 3 valid gas samples, and collect 95 percent of the 1-minute averages for meteorological data.

About 86 percent of the possible 1-minute data points that could be collected in an 8 day test period were determined to be valid. The remaining data were invalidated due to the failure of the site's booster compressor, which was not related to the performance of the COMM EVRU. The completeness goal for vent gas and discharge gas samples were exceeded, as four samples were collected from each gas stream.

3.2.1 Gas Recovery Rate

Gas recovery rate is defined as the difference between the discharge gas and motive gas compensated flow rates. The DQO for this verification parameter was to achieve an overall error of ± 20 percent. The sources of uncertainty (or measurement error) which contribute to this error include individual instrument errors for the motive gas and discharge gas flow rates.

The overall error of the motive gas flow measurement was determined to be ± 1.92 percent, and the overall error for the discharge gas flow measurement was ± 1.02 percent. The measurement errors associated with the motive and discharge gas flow instruments contribute to the error in the vent gas recovery rate computation. Using error propagation techniques described in the test plan, the actual error for the vent gas recovery rate was determined to be ± 9.68 percent, which is well below the ± 20 percent stated in the Test Plan. Therefore the DQO for gas recovery rate was achieved.

3.2.1.1 Motive Gas Flow Rate

The Test Plan specified the use of an integral orifice meter (Rosemount Model 3095) to measure the flow of motive gas to the EVRU. The integral orifice meter was factory calibrated prior to installation in the field, and the calibration records were reviewed to ensure the ± 1.0 percent instrument accuracy goal was achieved. The primary method of reconciling the accuracy goal for the motive gas rate was the factory calibration of the integral orifice meter components which include the temperature sensor, differential pressure sensor, and absolute pressure sensor. A pretest factory calibration certificate was obtained for the three sensors, and each met the specified ranges. Consequently, Roesmount certified the meter to be accurate within ± 1.0 percent.

A field verification of this meter was performed by isolating the vent gas line from the EVRU, and natural gas was allowed to flow through the orifice meter (located in the motive gas line) and the turbine meter (located in the discharge line). By doing this, the same volume of gas was flowing through each of the meters. Appendix F summarizes the results for three flow comparison tests. The absolute percent differences were ± 1.11, ± 2.73, and ± 5.13 percent at 550, 390, and 200 scfm, respectively.

During the test motive gas flow rates ranged between 327 and 613 scfm. Thus, the data quality results of the flow are considered representitive of actual flow conditions observed during testing. These data are used to reconcile the orifice meter error. The results indicate an average negative bias of about 1.92 percent, which is higher than the ± 1.0 percent factory calibration error. Consequently, the motive gas flow rates are assigned with a ± 1.92 percent measurement error.

3.2.1.2 Discharge Gas Flow Rate

As described earlier in Section 1.0, the discharge gas flow rate was not measured using the Rosemount integral orifice flow meter. An American Meter Company Model GTS-4 rotary turbine type gas meter was used as a replacement. The turbine meter measures gas flow in actual cubic feet (acf), therefore the discharge gas flow rate was converted to standard cubic feet (scf) using the measured gas pressure, temperature, and compressibility factor. The measurement errors for these variables were used to propagate the error for the gas recovery rate.

The turbine meter readings were converted to standard conditions using Equation 4:

$$V = V_g \left(\frac{P_g}{14.73} \right) \left(\frac{520}{T_g} \right) \left(\frac{Z_{std}}{Z_g} \right) \qquad \text{(Eqn. 4)}$$

Where:

V	= Discharge gas flow rate, scfm
V_g	= Turbine meter reading, acfm
P_g	= Discharge gas pressure, psia
T_g	= Discharge gas temperature, R (°F + 460)
Zstd	= Compressibility factor at standard conditions from discharge gas analysis
Zg	= Compressibility factor at actual conditions

Prior to testing, the turbine meter was calibrated with a volume prover at five flow levels that were within the meter's operating range. The average percent difference between the meter readings and the reference readings was determined to be ± 0.30 percent, and this value was assigned as the turbine meter error.

A pressure transducer and RTD were installed in the discharge line following American Gas Association procedures for sensor location (AGA 1996). These sensors were taken from the Rosemount gas flow meter previously installed on the discharge meter loop. Both sensors were factory calibrated with NIST traceable standards. The average results of a four point calibration check was determined to ± 0.023 percent for the pressure sensor and ± 0.006 percent for the temperature sensor.

Measurement error associated with the compressibility factor was reconciled by comparing analytical results of an audit gas submitted to the laboratory. As discussed later in Section 3.2.2, the overall average percent difference between the reference concentrations and the measured concentrations was ± 0.61 percent, and this value was assigned as the gas compressibility error.

The overall error in discharge gas flow measurement is ± 1.02 percent. This is based on error propagation of turbine meter error (± 0.30 percent), pressure (± 0.023 percent), temperature (± 0.006 percent), and compressibility factor (± 0.61 percent).

3.2.2 Annual Gas Savings and Emission Reductions

Annual gas savings are based on gas recovery rates, actual oil production rates during the testing period, and the projected annual oil production rate. As discussed earlier, the error in the gas recovery rate is ± 9.68 percent. The oil production rates (actual and projected) were obtained directly from the site and are assumed to be accurate. Consequently, the error in annual gas savings is estimated to be ± 9.68 percent.

Methane and HAP emission reductions are determined by multiplying the annual gas savings by the concentration of each pollutant. The error in this verification parameter is estimated to be ± 9.74 percent. This is based on the error associated with annual gas savings (discussed above), and vent gas compositional analysis results.

Four vent gas samples, four discharge gas samples, and two audit gas samples were collected using same sampling procedures. The audit gas samples were collected during two different days from an identifical gas cylinder of certified concentration. The audit gas is an independent Natural Gas GPA Reference Standard manufactured by Scott Specialty Gases with a certified accuracy of ± 2 percent. All gas samples collected in the field, were submitted to Core Laboratories in Houston, Texas for composition, heating value, and compressibility factor analysis. Duplicate analysis was performed on one vent gas sample, one discharge gas sample, and one audit gas sample.

As discussed earlier, the vent and discharge gas samples contained fairly high concentrations of nitrogen and oxygen. Because of these high concentrations, it is believed that there was air leakage into the canisters during the sample collection. Core Laboratories was able to normalize the vent and discharge gas data based on zero percent oxygen. After normalization, the vent and discharge gas concentrations were similar to pre-test samples. Therefore, the normalized vent and discharge samples collected during the verification test were used to quantify methane, BTEX, and HAP emissions. The duplicate analysis results for the vent and discharge gas samples were invalidated due to erroneous nitrogen levels in the samples. The data quality results presented here are based on the performance of the audit gas analysis.

Table 3-4 summarizes the results of the two audit gas samples. Sample number 2 was invalidated because it is suspected that, similar to vent gas and discharge gas samples, air contamination occurred during sampling. For sample Number 1, duplicate analysis resulted in a repeatability (precision) of ± 0.8 percent for CH_4. The duplicate analysis did not meet the DQI goals of ± 0.1 percent for compounds with concentrations greater than 10 mole percent. The maximum analytical error between the certified CH_4 concentration and the measured CH_4 concentration was ± 1.1 percent. This value is assigned as the error associated with methane concentration measurements, and is used to compute errors in emission reduction estimates.

The higher than expected error in concentration measurements are believed to result from poor sampling procedures in the field. They are not expected to be significantly affected by the analytical error of the laboratory, because as shown in Table 3-5, comparison with a continuous calibration standard (performed immediately prior to duplicate analysis) indicates a very close agreement among all gas species.

Table 3-4. Audit Gas Analysis Results						
Gas Component	**Certified Component Concentration (mole %)**	**Analytical Result (mole %)**	**Absolute Difference[a]**	**Combined Sampling and Analytical Error [b] (%)**	**Duplicate Analytical Result (mole %)**	**Analytical Repeatability [c](%)**
Audit Gas Sample 1						
Nitrogen	5.00	6.23	1.23	24.6	6.22	0.2
Methane	70.50	69.69	0.81	1.1	70.28	0.8
Ethane	9.01	9.02	0.01	0.1	9.04	0.2
Propane	6.03	6.09	0.06	1.0	6.06	0.5
n-Butane	3.01	2.99	0.02	0.7	2.98	0.3
Isobutane	3.01	3.02	0.01	0.3	3.00	0.7
n-Pentane	1.01	1.02	0.01	1.0	1.01	1.0
Isopentane	1.01	1.01	0.00	0.0	1.00	1.0
Average			**0.13**	**0.61**		**0.64**
Audit Gas Sample 2						
Nitrogen	5.00	7.02	2.02	40.4		
Methane	70.50	74.91	4.41	6.3		
Ethane	9.01	6.91	2.10	23.3		
Propane	6.03	3.69	2.34	38.8		
n-Butane	3.01	1.42	1.59	52.8		
Isobutane	3.01	1.39	1.62	53.8		
n-Pentane	1.01	0.58	0.43	42.6		
Isopentane	1.01	0.79	0.22	21.8		
Average			**1.82**	**34.20**		

[a] Certified Concentration – Measured Concentration
[b] (Certified Concentration – Measured Concentration) / Certified Concentration * 100
[c] (Measured Concentration – Duplicate Analysis Result) / Measured Concentration * 100

Table 3-5. GC/FID Calibration Results				
Gas Component	**Certified Component Concentration (mole %)**	**Analytical Result (mole %)**	**Absolute Difference[a]**	**Analytical Error (%)**
Audit Gas Sample 1				
Nitrogen	5.000	5.000	0.00	0.000
Methane	70.4870	70.487	0.00	0.000
Ethane	9.002	9.002	0.00	0.000
Propane	6.003	6.003	0.00	0.000
n-Butane	3.010	2.990	0.020	0.660
Isobutane	3.001	3.020	0.019	0.006
n-Pentane	1.000	1.000	0.000	0.000
Isopentane	0.998	1.000	.0020	0.002

[a] Certified Concentration – Measured Concentration

3.2.3 Value of Gas Recovered

The value of gas recovered in units of U.S. dollars per year, is the industry cost of natural gas multiplied by the annual cubic feet of gas saved. The industry average natural gas price was obtained through telephone conversations with the site manager and is assumed to be accurate. The natural gas price is a function of the heating value of the gas saved. The data quality of the gas recovered will depend on the data quality of the lower heating value (LHV) measurements. The DQI goal for LHV analysis is defined to be ± 0.2 percent, and propagated with the ± 20 percent gas recovery rate error to yield an overall ± 20 percent error in the value of gas recovered.

The natural gas price is a function of the heating value of the gas saved. The lower heating value was calculated using the normalized discharge gas sample results. The error in the heating values is directly related to the concentration measurements. As discussed earlier, the total error in compositional analysis is determined to be ± 0.61 percent (based on audit gas results). This equates to about a ± 7 Btu/ft^3 error in discharge gas heating values. The natural gas sales price is not expected to be affected by this variability.

The Test Plan specified a DQO of ± 20 percent for the annual cubit feet of gas saved. Actual error for this parameter was ± 9.68 percent (Section 3.2.2).

4.0 ADDITIONAL INFORMATION SUPPLIED BY COMM

Note: This section provides an opportunity for COMM Engineering to provide additional comments concerning the EVRU system and its features not addressed elsewhere in this Verification Report. The GHG Center has not independently verified the statements made in this section.

The Oil & Gas Industry is constantly moving toward new parameters at an ever-increasing pace. Stringent legislation and environmental regulation plus a general commitment to achieving efficient, cost reducing operations dictated change, while influencing government granted concessions. COMM Engineering, USA has utilized these new parameters as a departure point to develop processes and technologies that are unique in the industry.

Our mission is to revolutionize the meaning of energy efficiency and environmental benefits through innovative technological systems that are breaking the barriers of conventional operations. The vision of COMM Engineering, USA can be witnessed by some of our latest developments.

COMM Engineering's Environmental Vapor Recovery Unit (EVRU™) patented process utilizes supersonic velocities (kinetic energy) in place of shaft work to recover vent gases and boost them to a pressure that can be utilized or sold. Some of the benefits of the EVRU™ are listed below:

- Low capital and operational costs versus conventional mechanical vapor recovery units (VRU)
- No outside electrical power or fuel required to operate the EVRU™. Because it does not require fuel or electricity it is ideal for remote locations.
- System is closed loop, therefore no added emissions for the facility
- Meets all regulatory requirements for vapor control and there is no increase in the facility's emissions due to fuel consumption from a conventional VRU.
- The EVRU™ is compact. Deck space, which is at a premium, is not wasted. The system can be installed in the pipe rack above the vessels.
- No moving parts. With no moving parts there is nothing to wear out. Low- to no-maintenance costs.
- The EVRU™ is scalable. This allows the unit to accommodate increasing or decreasing production rates.
- The EVRU™ can be designed to operate in series. This style of operation allows the EVRU™ to boost the recovered gas to higher pressures in defined steps more efficiently.

This technology can be applied to many other processes outside of traditional vapor recovery. Each EVRU™ is designed to meet the customer's unique requirements. This allows the unit to be the most efficient technology for recovering what was previously thought to be a lost product.

5.0 REFERENCES

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APPENDICES

Appendix A

Pre-Test Motive Gas Samples

Sample Date:		**2/9/02**[a]	**5/8/02**
Compound	**Units**		
Oxygen	mol %	<0.01	<0.01
Nitrogen	mol %	0.080	0.094
Carbon Dioxide	mol %	0.154	0.318
Methane	mol %	88.284	87.145
Ethane	mol %	6.802	7.248
Propane	mol %	2.411	2.779
Isobutane	mol %	0.609	0.756
n-Butane	mol %	0.562	0.656
Isopentane	mol %	0.257	0.273
n-Pentane	mol %	0.183	0.184
Hexanes Plus	mol %	0.658	0.547
Total		100	100
Relative Density			0.665
Compressibility Factor			0.9970
Higher Heating Value (Dry/Real)	Btu/scf	1162	1171
Lower Heating Value (Dry)	Btu/scf		

[a] This gas composition was programmed into Rosemount motive gas flow meter

Appendix B

Pre-Test Vent Gas Samples

Sample Date:		**2/9/02**
Compound	**Units**	
Oxygen	mol %	<0.01
Nitrogen	mol %	0.063
Carbon Dioxide	mol %	0.124
Methane	mol %	56.903
Ethane	mol %	12.233
Propane	mol %	10.381
Isobutane	mol %	4.549
n-Butane	mol %	4.848
Isopentane	mol %	2.992
n-Pentane	mol %	2.180
Hexanes Plus	mol %	5.727
Total		100
Higher Heating Value (Dry/Real)	Btu/scf	1850

Appendix C

Vent Gas Samples Collected During Test

		As Received					Normalized to 0 % O_2 and 0.63 % N_2				
Sample Date:		**6/22/02 2:24 PM**	**6/26/02 11:00 AM**	**6/28/02 12:40 PM**	**6/30/02 3:00 PM**	**Average**	**6/22/02 2:24 PM**	**6/26/02 11:00 AM**	**6/28/02 12:40 PM**	**6/30/02 3:00 PM**	**Average**
Compound	**Units**										
Nitrogen	mol %	33.02	4.70	16.21	4.26	14.55	0.063	0.063	0.063	0.063	0.06
Oxygen	mol %	7.83	0.68	3.77	0.95	3.31	0.000	0.000	0.000	0.000	0.00
Carbon Dioxide	mol %	0.26	0.13	0.23	0.13	0.19	0.44	0.14	0.29	0.14	0.25
Methane	mol %	37.28	46.84	39.71	36.94	40.19	62.97	49.47	49.6	38.96	50.25
Ethane	mol %	4.77	10.09	7.94	12.02	8.71	8.06	10.66	9.92	12.67	10.33
Propane	mol %	4.26	12.00	8.61	15.34	10.05	7.20	12.68	10.75	16.17	11.70
Isobutane	mol %	2.14	5.73	4.3	7.05	4.81	3.62	6.05	5.37	7.43	5.62
n-Butane	mol %	2.49	6.22	4.85	7.45	5.25	4.21	6.57	6.06	7.85	6.17
Isopentane	mol %	1.67	3.47	2.99	3.94	3.02	2.82	3.67	3.73	4.15	3.59
n-Pentane	mol %	1.27	2.49	2.22	2.78	2.19	2.15	2.63	2.77	2.93	2.62
Hexanes Plus	mol %	5.01	7.65	9.17	9.14	7.74	8.47	8.07	11.45	9.64	9.41
2,2-Dimethylbutane	mol %	0.151	0.276	0.260	0.309	0.249	0.255	0.292	0.325	0.326	0.300
2-Methyl Pentane	mol %	0.553	0.994	0.973	1.026	0.887	0.934	1.050	1.215	1.082	1.070
3-Methyl Pentane	mol %	0.503	0.813	0.804	0.957	0.769	0.850	0.859	1.004	1.009	0.930
n-Hexane	mol %	0.623	1.032	1.052	1.126	0.958	1.052	1.090	1.314	1.187	1.161
Methylcyclopentane	mol %	0.392	0.622	0.659	0.698	0.593	0.662	0.657	0.823	0.736	0.720
Benzene	mol %	0.312	0.480	0.546	0.568	0.477	0.527	0.507	0.682	0.599	0.579
Cyclohexane	mol %	0.442	0.684	0.764	0.787	0.669	0.747	0.723	0.954	0.830	0.813
2-Methyl Hexane	mol %	0.199	0.306	0.356	0.339	0.300	0.336	0.323	0.445	0.357	0.365
3-Methyl Hexane	mol %	0.156	0.233	0.273	0.264	0.232	0.264	0.416	0.577	0.477	0.434
Dimethylcyclopentanes	mol %	0.109	0.161	0.189	0.188	0.162	0.184	0.000	0.000	0.000	0.046
n-Heptane	mol %	0.282	0.409	0.506	0.488	0.421	0.476	0.432	0.632	0.515	0.514
Methylcyclohexane	mol %	0.402	0.572	0.725	0.697	0.599	0.679	0.604	0.905	0.735	0.731
Trimethylcyclopentanes	mol %	0.047	0.065	0.077	0.074	0.066	0.079	0.069	0.096	0.078	0.081
Toluene	mol %	0.241	0.306	0.427	0.409	0.346	0.407	0.323	0.533	0.431	0.424
2-Methylheptane	mol %	0.068	0.092	0.145	0.045	0.088	0.115	0.097	0.181	0.047	0.110
3-Methylheptane	mol %	0.004	0.006	0.010	0.008	0.007	0.007	0.006	0.012	0.008	0.008
Dimethylcyclohexanes	mol %	0.100	0.133	0.220	0.184	0.159	0.169	0.140	0.275	0.194	0.194
n-Octane	mol %	0.111	0.143	0.258	0.209	0.180	0.188	0.151	0.322	0.220	0.220
EthylBenzene	mol %	0.020	0.019	0.041	0.030	0.028	0.034	0.020	0.051	0.032	0.034
Xylenes (Total)	mol %	0.082	0.077	0.054	0.040	0.063	0.139	0.081	0.067	0.042	0.082
C9 Naphthenes	mol %	0.026	0.054	0.080	0.229	0.097	0.044	0.057	0.100	0.241	0.110
C9 Paraffins	mol %	0.054	0.058	0.139	0.106	0.089	0.091	0.061	0.174	0.112	0.110
N-nonane	mol %	0.050	0.051	0.324	0.229	0.164	0.084	0.054	0.405	0.241	0.196
Decanes Plus	mol %	0.083	0.058	0.285	0.129	0.139	0.140	0.061	0.356	0.136	0.173
Total		100.00	100.00	100.00	100.00	100.00	100.003	100.01	100.00	100.00	100.000
Relative Density		1.061	1.245	1.262	1.389	1.239	1.112	1.261	1.333	1.412	1.280
Compressibility Factor		0.99517	0.98824	0.98938	0.98495	0.98944	0.98992	0.98715	0.98497	0.98359	0.98641
Higher Heating Value (Dry/Real)	Btu/scf	1091	1980	1751	2204	1756	1835	2068	2164	2290	2089
Lower Heating Value (Dry)	Btu/scf	999	1818	1610	2027	1613	1682	1898	1989	2106	1919

Appendix D

Pre-Test Discharge Gas Samples

Sample Date:		**6/4/02**	**6/4/02**	**6/5/02**	**6/5/02**	**6/6/02**	**6/6/02**	**Average**
Sample Time:		**7:30 am**	**4:00 pm**	**8:00 am**	**3:00 pm**	**7:30 am**	**2:30 pm**	
Compound	**Units**							
Oxygen	mol %	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Nitrogen	mol %	0.14	0.16	0.09	0.15	0.13	0.36	0.17
Carbon Dioxide	mol %	0.12	0.1	0.11	0.09	0.09	0.13	0.11
Methane	mol %	79.45	78.04	80.44	79.33	86.89	78.62	80.46
Ethane	mol %	8.18	8.18	8.03	8.17	7.17	8.05	7.96
Propane	mol %	4.77	4.77	4.46	4.66	2.83	4.49	4.33
Isobutane	mol %	1.82	1.86	1.63	0.18	0.77	1.82	1.35
n-Butane	mol %	1.81	1.94	1.62	1.84	0.7	1.82	1.62
Isopentane	mol %	0.93	1.05	0.84	1	0.3	1	0.85
n-Pentane	mol %	0.66	0.77	0.59	0.73	0.21	0.72	0.61
Hexanes Plus	mol %	2.12	3.13	2.19	3.85	0.91	2.99	2.53
Total		100	100	100	100	100	100	100
2,2-Dimethylbutane	mol %	0.075	0.091	0.068	0.086	0.024	0.087	0.07
2-Methyl Pentane	mol %	0.25	0.345	0.229	0.323	0.085	0.316	0.26
3-Methyl Pentane	mol %	0.24	0.274	0.217	0.271	0.072	0.265	0.22
n-Hexane	mol %	0.28	0.365	0.268	0.354	0.099	0.347	0.29
Methylcyclopentane	mol %	0.167	0.221	0.16	0.218	0.061	0.209	0.17
Benzene	mol %	0.145	0.203	0.206	0.25	0.044	0.2	0.17
Cyclohexane	mol %	0.19	0.264	0.186	0.261	0.07	0.245	0.20
2-Methyl Hexane	mol %	0.085	0.112	0.075	0.117	0.035	0.109	0.09
3-Methyl Hexane	mol %	0.062	0.09	0.062	0.094	0.027	0.086	0.07
Dimethylcyclopentanes	mol %	0.044	0.064	0.043	0.066	0.019	0.056	0.05
n-Heptane	mol %	0.11	0.172	0.113	0.188	0.054	0.163	0.13
Methylcyclohexane	mol %	0.16	0.243	0.165	0.271	0.072	0.224	0.19
Trimethylcyclopentanes	mol %	0.018	0.031	0.02	0.035	0.009	0.032	0.02
Toluene	mol %	0.098	0.162	0.113	0.198	0.05	0.153	0.13
2-Methylheptane	mol %	0.025	0.046	0.027	0.058	0.017	0.045	0.04
3-Methylheptane	mol %	0.013	0.024	0.014	0.031	0.009	0.022	0.02
Dimethylcyclohexanes	mol %	0.026	0.049	0.027	0.061	0.018	0.046	0.04
n-Octane	mol %	0.038	0.081	0.047	0.104	0.032	0.078	0.06
Ethyl Benzene	mol %	0.005	0.01	0.007	0.017	0.004	0.011	0.01
Xylenes (Total)	mol %	0.027	0.068	0.042	0.474	0.028	0.068	0.12
C9 Naphthenes	mol %	0.009	0.025	0.015	0.04	0.007	0.023	0.02
C9 Paraffins	mol %	0.016	0.039	0.023	0.061	0.016	0.042	0.03
n-Nonane	mol %	0.013	0.048	0.024	0.078	0.014	0.049	0.04
Decanes Plus	mol %	0.029	0.101	0.039	0.191	0.042	0.114	0.09
Total		2.125	3.128	2.19	3.847	0.908	2.99	2.53
Total HAP		0.555	0.808	0.636	1.293	0.225	0.779	0.72
Relative Density		0.783	0.820	0.773	0.815	0.676	0.810	0.77932
Compressibility Factor		0.99556	0.99498	0.99566	0.99489	0.99684	0.99514	0.99551
Higher Heating Value (Dry/Real)	Btu/scf	1359	1415	1343	1404	1195	1395	1351.9
Lower Heating Value (Dry)	Btu/scf	1236	1288	1221	1279	1082	1270	1229

Appendix E

Discharge Gas Samples Collected During Test

		As Received					Normalized to 0 % O_2 and 0.17 % N_2				
Sample Date:		**6/22/02**	**6/26/02**	**6/28/02**	**6/30/02**	**Average**	**6/22/02**	**6/26/02**	**6/28/02**	**6/30/02**	**Average**
Sample Time:		**12:45 PM**	**11:15 AM**	**12:30 PM**	**2:50 PM**		**12:45 PM**	**11:15 AM**	**12:30 PM**	**2:50 PM**	
Compound	**Units**										
Oxygen	mol %	0.45	0.3	0.02	1.05	0.46	0.00	0.00	0.00	0.00	0.00
Nitrogen	mol %	8.68	1.62	2.06	5.56	4.48	0.17	0.17	0.17	0.17	0.17
Carbon Dioxide	mol %	0.91	0.09	0.09	0.1	0.30	1.00	0.09	0.09	0.11	0.32
Methane	mol %	67.93	83.68	77.58	77.01	76.55	74.63	85.17	79.09	82.32	80.30
Ethane	mol %	8.71	6.8	7.7	7.09	7.58	9.57	6.92	7.85	7.58	7.98
Propane	mol %	5.73	3.3	4.67	3.89	4.40	6.29	3.36	4.76	4.16	4.64
Isobutane	mol %	2.87	1.09	1.83	1.34	1.78	3.15	1.11	1.87	1.43	1.89
n-Butane	mol %	2.81	1.03	1.89	1.34	1.77	3.09	1.05	1.93	1.43	1.88
Isopentane	mol %	0.89	0.49	1.01	0.66	0.76	0.98	0.50	1.03	0.71	0.81
n-Pentane	mol %	0.89	0.35	0.74	0.46	0.61	0.98	0.36	0.75	0.49	0.65
Hexanes Plus	mol %	0.13	1.25	2.41	1.5	1.32	0.14	1.27	2.46	1.60	1.37
Total		100	100	100	100	100	100	100	100	100	100
Relative Density		0.822	0.710	0.800	0.758	0.773	0.807	0.705	0.797	0.742	0.76258
Compressibility Factor		0.99606	0.99669	0.99569	0.9965	0.99624	0.99550	0.99661	0.99557	0.99621	0.99597
Higher Heating Value (Dry/Real)	Btu/scf	1247	1214	1351	1209	1255	1370	1236	1377	1293	1319
Lower Heating Value (Dry)	Btu/scf	1134	1101	1228	1098	1140	1246	1121	1252	1173	1198

Appendix F

Flow Through Comparison Results Between Turbine Meter and Orifice Meter

Date	Time	Ambient Temp. (F)	Discharge Gas Pressure (psia)	Discharge Gas Temp. (F)	Turbine Meter Flow Rate (acfm)	Turbine Meter Flow Rate (scfm)	Orifice Meter Flow Rate (scfm)	Percent Difference[a] Between Turbine Meter Reading and Orifice Meter Reading (%)
6/23/02	12:10 PM	89.91	37.19	54.95	217.83	558.13	550.53	1.36
6/23/02	12:11 PM	90.15	37.11	55.04	218.35	558.11	550.37	1.39
6/23/02	12:12 PM	90.90	38.02	55.13	212.39	556.08	550.68	0.97
6/23/02	12:13 PM	91.48	38.05	55.35	214.17	560.99	552.44	1.52
6/23/02	12:14 PM	91.52	37.69	55.52	214.58	556.58	550.70	1.06
6/23/02	12:15 PM	91.27	36.17	55.57	222.65	554.09	552.42	0.30
6/23/02	12:16 PM	90.75	38.15	55.57	211.95	556.40	550.52	1.06
6/23/02	12:17 PM	90.10	37.55	55.44	215.08	555.82	553.70	0.38
6/23/02	12:18 PM	89.97	35.77	55.31	226.39	557.44	552.53	0.88
6/23/02	12:19 PM	89.76	37.85	55.20	217.71	567.49	551.43	2.83
6/23/02	12:20 PM	89.73	37.59	54.88	213.54	553.12	551.48	0.30
6/23/02	12:21 PM	89.75	37.70	54.67	215.98	561.22	552.41	1.57
6/23/02	12:22 PM	90.31	36.19	54.72	223.69	557.98	552.29	1.02
6/23/02	12:23 PM	90.41	37.46	54.89	215.42	556.03	553.14	0.52
6/23/02	12:24 PM	90.29	38.00	55.11	214.55	561.47	553.11	1.49
Average		90.42	37.37	55.16	216.95	**558.06**	**551.85**	**1.11**
6/23/02	12:40 PM	90.87	33.55	55.99	170.21	392.66	381.49	2.85
6/23/02	12:41 PM	91.36	33.36	56.39	169.31	387.99	380.23	2.00
6/23/02	12:42 PM	91.10	33.26	56.26	170.14	388.85	380.71	2.09
6/23/02	12:43 PM	90.55	34.54	56.33	164.30	389.95	380.53	2.42
6/23/02	12:44 PM	90.63	33.46	55.86	171.52	394.73	381.39	3.38
6/23/02	12:45 PM	90.73	31.67	56.07	177.13	385.62	382.24	0.88
6/23/02	12:46 PM	90.74	35.73	55.76	161.21	396.18	380.73	3.90
6/23/02	12:47 PM	90.41	32.23	55.68	179.51	398.02	380.97	4.29
6/23/02	12:48 PM	90.21	34.52	55.62	162.63	386.29	379.93	1.65
6/23/02	12:49 PM	90.14	33.55	55.38	169.54	391.51	381.32	2.61
6/23/02	12:50 PM	90.24	32.12	55.48	176.94	391.08	381.60	2.42
6/23/02	12:51 PM	90.32	32.58	55.60	173.37	388.65	381.62	1.81
6/23/02	12:52 PM	90.14	35.40	55.29	159.86	389.59	382.39	1.85
6/23/02	12:53 PM	90.17	31.73	55.27	181.26	395.92	381.87	3.55
6/23/02	12:54 PM	90.20	33.56	55.35	173.26	400.31	381.06	4.81
6/23/02	12:55 PM	90.29	33.81	54.90	168.61	392.77	382.37	2.65
6/23/02	12:56 PM	90.56	33.80	55.01	168.29	391.83	381.54	2.63
6/23/02	12:57 PM	90.80	36.48	54.98	156.04	392.13	380.28	3.02
6/23/02	12:58 PM	90.43	32.26	55.24	177.74	394.75	382.70	3.05
Average		90.52	33.56	55.60	170.05	**392.04**	**381.31**	**2.73**
6/23/02	1:03 PM	89.84	28.41	62.87	110.02	212.05	197.13	7.03
6/23/02	1:04 PM	89.85	26.82	61.68	117.33	214.00	199.28	6.88
6/23/02	1:05 PM	89.82	27.27	69.78	114.83	209.71	200.30	4.49
6/23/02	1:06 PM	89.92	29.15	65.68	107.13	210.74	198.44	5.83
6/23/02	1:07 PM	90.20	26.86	62.89	114.98	209.52	198.37	5.32
6/23/02	1:08 PM	90.61	27.56	63.07	109.35	204.39	198.76	2.76
6/23/02	1:09 PM	91.22	28.52	61.56	109.15	211.75	198.19	6.40
6/23/02	1:10 PM	91.04	26.61	63.23	116.24	209.69	200.31	4.47
6/23/02	1:11 PM	90.52	29.73	63.50	103.04	207.59	198.97	4.15
6/23/02	1:12 PM	91.01	26.02	63.35	120.26	212.10	199.06	6.15
6/23/02	1:13 PM	91.56	28.56	63.75	107.53	207.99	199.04	4.30
6/23/02	1:14 PM	91.65	29.25	63.89	107.48	212.86	198.04	6.96
6/23/02	1:15 PM	91.16	25.56	63.75	122.88	212.74	197.82	7.01
6/23/02	1:16 PM	91.13	29.46	63.95	103.82	207.09	198.60	4.10
6/23/02	1:17 PM	91.07	25.94	63.56	118.45	208.18	198.74	4.54
6/23/02	1:18 PM	90.60	28.96	63.65	104.08	204.20	198.63	2.73
6/23/02	1:19 PM	90.71	27.95	63.38	113.50	215.02	198.42	7.72
6/23/02	1:20 PM	91.42	26.26	63.26	120.84	215.11	199.15	7.42
6/23/02	1:21 PM	91.73	28.53	63.44	109.99	212.65	198.18	6.81
Average		90.79	27.76	63.70	112.15	**210.39**	**198.71**	**5.53**

[a] = 100 * (Turbine Meter Reading - Orifice Meter Reading) / Turbine Meter Reading